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**An Architectural Analysis and Earthen Finish  
Characterization of Cavate M-100, Frijoles  
Canyon, Bandelier National Monument,  
Los Alamos, NM**

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A THESIS

In

Historic Preservation

Presented to the Faculties of the University of Pennsylvania in  
Partial Fulfillment of the Requirements for the Degree of

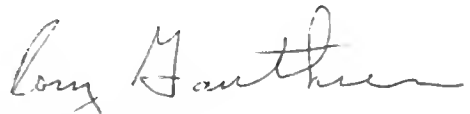
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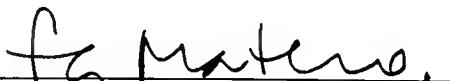
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## Table of Contents

<b>INTRODUCTION.....</b>	<b>1</b>
<b>CHAPTER 1: HISTORY OF BANDELIER NATIONAL MONUMENT.....</b>	<b>5</b>
1.1 Environment.....	5
1.1.1 Geology.....	5
1.1.2 Soils.....	8
1.1.3 Climate.....	8
1.1.4 Vegetation.....	9
1.1.5 Wildlife.....	9
1.2 Archaeological Excavation Campaigns.....	10
1.3 Stabilization Campaigns.....	11
1.4 Site Preservation and Presentation.....	14
<b>CHAPTER 2: CAVATE ARCHITECTURE AT BANDELIER NATIONAL MONUMENT.....</b>	<b>19</b>
2.1 Frijoles Canyon.....	19
2.2 Group M.....	20
2.3 Cavate M-100.....	22
2.4 Documentation and Recordation.....	23
2.4.1 Methodology.....	23
2.4.1 Digital Documentation.....	25
2.5 Annotated Drawings.....	28
2.6 Comparison with Historic Photographs.....	35
<b>CHAPTER 3: INTERIOR FINISHES ANALYSIS AND CHARACTERIZATION OF CAVATE M-100.....</b>	<b>36</b>
3.1 Field Observations.....	38
3.2 Sampling.....	41
3.3 Thin Section Analysis.....	43
3.3.1 Methodology.....	43
3.3.2 Analysis.....	45
3.4 pH and Conductance.....	59
3.5 Conclusions.....	62
<b>CHAPTER 4: CONCLUSIONS.....</b>	<b>64</b>
4.1 Interior Finishes.....	64
4.2 Embellishments.....	72
4.3 Mechanisms of Deterioration.....	75



<b>CHAPTER 5: RECOMMENDATIONS.....</b>	<b>77</b>
<b>BIBLIOGRAPHY.....</b>	<b>79</b>
<b>ILLUSTRATIONS.....</b>	<b>85</b>
 <b>APPENDICIES</b>	
Appendix A: Field Manual.....	93
Appendix B: Annotated Drawings.....	100
Appendix C: Embellishment Survey.....	106
Appendix D: Thin Section Micromorphology.....	122
Appendix E: Conjectural Finish Schemes.....	155
Appendix F: Glossary of Thin Section Terms.....	159
 <b>INDEX.....</b>	 <b>164</b>



## List of Figures

<i>Figure 1. Cavates in Frijoles Canyon.....</i>	<i>1</i>
<i>Figure 2. Cavates in Group M.....</i>	<i>2</i>
<i>Figure 3. View of Frijoles Canyon, looking west.....</i>	<i>5</i>
<i>Figure 4. Occupation Periods of Frijoles Canyon.....</i>	<i>20</i>
<i>Figure 5. Cavate M-100.....</i>	<i>21</i>
<i>Figure 6. Documentation in Cavate M-100.....</i>	<i>22</i>
<i>Figure 7. Plan of Group M East, Frijoles Canyon.....</i>	<i>27</i>
<i>Figure 8. Elevation of Group M East, Frijoles Canyon.....</i>	<i>27</i>



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## INTRODUCTION

In North America, cavate structures represent a small but unique type of indigenous architecture in the southwestern United States, especially in northern New Mexico and Arizona. Cavates have been defined as “cavities in the canyon wall that are primarily the result of excavation of the rock.”<sup>1</sup> Unlike most of the archaeological record, cavates are easily documented without excavation. They are similar to dry caves, although they are human-made, and as such they preserve many fragile features that otherwise would be destroyed. These features include earthen architectural finishes and organic materials, as well as full walls and intact ceilings, all preserved remarkably well.<sup>2</sup> (*See Figure 1*)

The architectural significance of the cavate pueblos lies in their unique construction, and that they are one of the largest, well-preserved concentration of cavates in New Mexico. The cavates are grouped, often interconnected, hand-enlarged rock chambers in the cliffs clustered together as a village. Cavates generally formed the back rooms of stone multi-story residential units. Most of the anterior masonry structures have since collapsed, exposing the cavates. The cavate pueblos preserve an irreplaceable record of the past that is vital to understanding the native peoples who built and inhabited the area since the twelfth century.

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<sup>1</sup> H. Wolcott Toll, *An Analysis of the Variability and Condition of Cavate Structures in Bandelier National Monument* (United States Department of the Interior, 1995) p.1.

<sup>2</sup> Ibid, p.2.





Cavates are architecturally unique because many retain fragile architectural features rarely preserved in exposed architecture from that time period. Cavates contain walls and niches with painted earthen plasters; thick earthen floors with floor ridges, hearths, and loom anchors; plastered passageways that interconnect cavates; and sooted ceilings with carved vents. Pictographs and petroglyphs representing masked anthropomorphic figures, zoomorphs, hunting scenes, and geometric patterns are present in certain cavates.<sup>3</sup>

Cavate accessibility, while beneficial for archaeologists, creates a conservation issue. They are easily accessible to the public and vandals, which can lead to severe damage, intentional or not. Constructed out of tuff—a soft, extrusive volcanic rock—cavates are prone to natural deterioration from wind, water and salts, and visitor abrasion.

Cavates pose a unique problem for conservators and archaeologists alike. They are often small, dark and irregularly shaped, rendering the use of traditional documentation techniques difficult. The interiors of these spaces are extraordinarily fragile, and are often finished with earthen plasters and embellishments in the soot and plaster.

The first objective of this thesis is to record the interior of Cavate M-100, Frijoles Canyon, Bandelier National Monument as a model documentation and condition assessment project, using digital techniques developed by the

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<sup>3</sup> Angelyn Rivera, Bandelier National Monument, personal communication with the author, April 11, 2001.



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University of Pennsylvania for the ongoing Conservation of Architectural Surfaces Program for Archaeological Resources (C.A.S.P.A.R.) project at Mesa Verde National Park. Cavate M-100 was first field surveyed using photographic methods. This information was then digitized and manipulated using the various software applications. While a cavate space differs from the spaces being documented at Mesa Verde, it is hoped that the techniques can be applied here with similar results. The surveys have several uses. They record basic quantitative information about a space and its finishes, existing conditions, and serve as templates for future documentation. They are also useful diagnostic tools; this survey will be used in the near future to develop a conservation plan for Cavate M-100. This information will also be useful for archaeologists to further define architectural variability within the cavates.

The second objective of the thesis is the analysis and characterization of the earthen architectural finishes in Cavate M-100. Samples representing full stratigraphies of the finishes were taken and were examined microscopically to identify the sequence and composition of the finishes. This method of analysis has not been undertaken at the Park until now, despite the recognized importance of the cavates and the predominance of surviving interior finishes.

Earthen architectural finishes are recognized as a space-defining element in Puebloan architecture. There is a division of space suggested by the application of the finishes, and this division changes through time. This thesis will use the documentation of the space and the use of these finishes to communicate spatial differentiation within the cavate. This architectural analysis



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may contribute information in later explorations of possible relationships between surface treatment, room use and meaning.

Cavate M-100 is also heavily embellished with incised figures. The original meaning of these embellishments is not known, but where and how they were applied is of critical use and interest, and may contribute to greater understandings about the meaning of these spaces and habitation/use areas over time. Their recordation and conservation is of the highest priority.

In conjunction with archival research and on-site observation, research was conducted with the following questions in mind:

1. What was the appearance of the cavate over time?
2. How do the earthen architectural finishes delineate space? Do they define activity and/or living zones?
3. What is the composition of the finishes? Do the finishes change through time as superimposed campaigns?
4. What colorants, aggregates and binders were used?
5. Do the finishes suggest continuities or changes in spatial treatment, use and meaning?
6. What factors have affected the condition of the finishes over time?



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## Chapter One

### HISTORY OF BANDELIER NATIONAL MONUMENT

Bandelier National Monument is located 46 miles west of Santa Fe in north central New Mexico, on the southern Pajarito Plateau. The area forms part of the Rio Grande Rift Valley. The Monument was established on February 11, 1916 by President Woodrow Wilson to protect the ancient Pueblo settlements that “are of unusual ethnologic, scientific and educational interest”.<sup>4</sup> This area of archaeological wealth was brought to eminence due to the work of Adolph Bandelier during his survey work in the 1870s and 1880s, and became a national monument, in large part to the political and preservation-minded influence of Bandelier’s protégé, Edgar L. Hewett.

Cavates are found throughout the 132 km sq area of Bandelier National Monument, however the cavates located within Frijoles Canyon are the most numerous and famous.<sup>5</sup>

#### **Environment**

##### *1.1.1 Geology*

The Pajarito Plateau was formed between 1.4 and 1.1 million years ago, as a result of the massive eruptions of the Valles and Toledo volcanoes. These eruptions formed the Jemez Mountains, which lie to the west of the Monument, and deposited a layer of ash, which consolidated into an approximately 300 m thick blanket of soft tuff that comprises much of the Pajarito Plateau.

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<sup>4</sup> Presidential Proclamation, 1916.

<sup>5</sup> *The Bandelier Archaeological Survey, Volume 1*. Robert P. Powers and Janet D. Orcutt, eds., (United States Department of the Interior, 1999), p.1.





There are two layers of what is collectively known as Bandelier Tuff: the Otowi member, which is overlain by the Tshirege member. The Otowi Tuff consists of Plinian pumice-fall deposit, and was the result of an eruption 1.45 million years ago. The Tshirege member of Bandelier Tuff is the result of a volcanic eruption 1.12 million years ago, and consists of a basal pumice-fall.<sup>6</sup>

These layers are defined as:

Upper Bandelier Tuff (Tshirege Member)—White to tan to pink welded rhyolitic ash-flow containing abundant phenocrysts of sanidine and quartz and trace clinopyroxene, hypersthene and fayalite. Sanidine typically displays a blue iridescence; consists of several flow units in a compound cooling unit; locally contains a thin (.05m) nonwelded laminated ash-fall deposit at base unit (Tsankawi Pumice) that contains roughly 1% hornblend latite pumice (Bailey *et al.* 1969); locally may contain abundant rock fragments from nearby volcanic sources; Qbt (map symbol) forms conspicuous pink cliffs throughout the Pajarito Plateau; originated from catastrophic eruptions that formed the Valles Caldera; K-Ar age 1.12 $\pm$ 0.03 Ma; maximum observed thickness about 120m.

Lower Bandelier Tuff (Otowi Member)—White to pink, welded rhyolitic ash-flow tuff containing abundant phenocrysts of sanidine and quartz and sparse mafic phenocrystal sanidine may display blue iridescence; consists of several flow units in a compound cooling unit; locally contains a nonwelded laminate to poorly sorted ash-fall deposit at abundant volcanic and Paleozoic rock fragments; Qbo (map symbol) discontinuously fills in rugged topography on a pre-Toledo caldera age volcanic surface; forms thick deposit west of St. Peter's Dome area; very difficult to distinguish from upper Bandelier Tuff in hand samples; best distinguished by poorer degree of welding, more abundant lithic fragments, less abundant iridescent sanidine, and stratigraphic position beneath the Tsankawi pumice; originated from catastrophic eruptions that formed the Toledo caldera; K-Ar age 1.45 $\pm$ 0.06 Ma, maximum observed thickness about 150m.<sup>7</sup>

<sup>6</sup> Grant Heiken et al. "The Valles/Toledo Caldera Complex, Jemez Volcanic Field, New Mexico." *The Annual Review of Earth and Planetary Sciences*, (Vol.18, 1990), p.38-39.

<sup>7</sup> Stephen Goff et al. "The Valles/Toledo Caldera Complex, Jemez Volcanic Field, New Mexico."



The erosion of this tuff has resulted in the typical topography of the Plateau: long and narrow mesa tops separated by deep canyons. Below this layer of tuff lies earlier deposits of basalt, tuff and sandstone.<sup>8</sup> The cavates occur primarily in the Tshirege layer of the tuff.<sup>9</sup>

Samples of these two types of tuff were taken from the Park, and tested and analyzed by the Architectural Conservation Laboratory (ACL) at the University of Pennsylvania in 1998, as part of the Tsankawi Mesa Preservation Study. Tests included abrasion resistance, freeze/thaw and water absorption, as well as qualitative determination of soluble salts, depth of penetration and petrographic analysis. The results of these tests will be discussed in Chapter Three.<sup>10</sup>

### 1.1.2 Soils

Much of the soil materials present in the Park are volcanic, and they include rhyolites, andesites, tuff, pumice, and basalts. The pumiceous soils were deposited in another series of volcanic eruptions, the El Cajete eruptions, which occurred approximately 60,000-50,000 years ago. Much of this type of soil is found on the mesa tops of the monument, and as hill slopes in many canyons.<sup>11</sup>

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*The Annual Review of Earth and Planetary Sciences*, (Vol.18, 1990), In Shaun Provencher, *Cultural Landscape Preservation Issues—Tsankawi Mesa, Bandelier National Monument* (master's thesis, University of Pennsylvania, 1998), p.25-26.

<sup>8</sup> *The Bandelier Archaeological Survey, Volume 1*. Robert P. Powers and Janet D. Orcutt, eds., (United States Department of the Interior, 1999), p.7.

<sup>9</sup> *An Analysis of Variability and Condition of Cavate Structures in Bandelier National Monument*. H. Wolcott Toll, (United States Department of the Interior, 1995), 16.

<sup>10</sup> *Trail Preservation Study, Tsankawi Mesa, Bandelier National Monument, Los Alamos County, NM, National Park Service, USDI*. Prepared by Frank G. Matero, T. Scott Kreilick and Gomaa I. Omar, January 1998-May 1998, p. 118-119.

<sup>11</sup> *The Bandelier Archaeological Survey, Volume 1*. Robert P. Powers and Janet D. Orcutt, eds.,



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### 1.1.3 *Climate*

The climate of Bandelier National Monument is a semiarid continental mountain climate. There is a considerable amount of variability in the general area, however, due to changes in elevation and topography. Generally, it is sunny and dry, with short, heavy thunderstorms from the west in the mid- to late summer months. The average annual precipitation at Bandelier National Monument headquarters (1925-1987) is 40.7 cm, but is quite variable. The majority of precipitation occurs during the late summer months, resulting in about 60% of the annual precipitation. Dendroclimatological records, and other paleoclimate studies indicate that modern climate and vegetation patterns developed in the Bandelier area during the early Holocene, ca. 11,000 to 8,000 years ago B.P.<sup>12</sup>

### 1.1.4 *Vegetation*

As a result of the variations in elevation, exposure, topography, and the presence of a permanent stream, El Rito de los Frijoles, the canyon is able to support a wider range of flora and fauna than other areas. The presence of a permanent stream is possibly what originally attracted people to Frijoles Canyon. In other smaller, drier canyons only a limited amount of vegetation can be supported, such as stands of juniper and pinyon pine. The bottom of Frijoles supports a number of species of trees, including narrowleaf cottonwood, scouler willow, box elder, water birch, and mountain alder. Mesa tops below 1,920m are

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(United States Department of the Interior, 1999), p.7.

<sup>12</sup> Ibid, p.11.



covered with juniper grasslands. Shrubs such as yucca, cacti, mountain mahogany, apache plume, snakeweed and Gambel oak are also common.<sup>13</sup>

#### 1.1.5 Wildlife

With the ability to support a diverse range of vegetation also comes the ability to support a wide range of wildlife in Frijoles Canyon, as well as the rest of the Monument. According to faunal surveys, at least 190 vertebrate species (5 amphibians, 14 reptiles, 44 terrestrial mammals, 12 bats, and at least 115 breeding birds) and 1,200 arthropod species are present within the park.<sup>14</sup>

## 1.2 Archaeological Excavation Campaigns

Frijoles Canyon first became well known with Adolph Bandelier, who recorded his visits to the Canyon beginning in 1880. He subsequently published a novel about the area, *The Delight Makers*, in 1890. The cavates were visited at various times following Bandelier's visits, by the Bureau of American Ethnology in 1882 and 1886, and by tourists in the early twentieth century.<sup>15</sup>

Edgar L. Hewett began working in Frijoles Canyon in 1908 and 1909, clearing some of the cavates, as well as excavating. He excavated and cleared rooms A-K in Long House (Group D); cleared Group E, including Snake Kiva; excavated the kiva at Ceremonial Cave; and excavated Tyuonyi, including the

<sup>13</sup> *The Bandelier Archaeological Survey, Volume 1*. Robert P. Powers and Janet D. Orcutt, eds., (United States Department of the Interior, 1999), p.12.

<sup>14</sup> *Ibid*, p. 15.

<sup>15</sup> *An Analysis of Variability and Condition of Cavate Structures in Bandelier National Monument*. H. Wolcott Toll, (United States Department of the Interior, 1995), p.5.





Big Kiva.<sup>16</sup> He also defined the 13 groups of cavates/talus sites, which he labeled A through M, all located on the north side of Frijoles Canyon. Kenneth Chapman, who prepared a map of the Canyon for Hewett, conducted surveys of his own, published in 1916 and 1938, primarily of the “cave art” of the region. He photographed the various embellishments in the cavates at Bandelier.<sup>17</sup>

J.W. Hendron (1940, 1943) excavated 5 masonry rooms and their 4 associated cavates in Group M (LA #50972), and carefully recorded his findings. His intent for excavation was to stabilize the structures. The remains in the rooms, including Tewa blackware and cow bone, indicated that the rooms had been used historically, possibly during the Pueblo Revolt of 1680. Hendron’s descriptions of the interiors of the cavates included plaster dados, smoke vents, firepits, depressions on the floors, and a basalt threshold.<sup>18</sup> (*See Figure 2*)

More recently, H. Wolcott Toll conducted a survey of the cavates in Frijoles Canyon and Tsankawi Mesa, *An Analysis of Variability and Condition of Cavate Structures in Bandelier National Monument* (1995). Robert Powers *et al*, also conducted a broader, more thorough survey of the archaeology of 43% of the Park, *The Bandelier Archaeological Survey* (1999).

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<sup>16</sup> Edgar L. Hewett, revised by Bertha P. Dutton, *The Pajarito Plateau and its Ancient People*, 2<sup>nd</sup> ed. (University Of New Mexico Press, 1953) p.85-100.

<sup>17</sup> *An Analysis of Variability and Condition of Cavate Structures in Bandelier National Monument*. H. Wolcott Toll, (United States Department of the Interior, 1995), p.8.

<sup>18</sup> *Ibid*, p.9.



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### 1.3 Stabilization Campaigns

Of the 1008 cavates in Bandelier National Monument, only 10% have received any stabilization. Most of the stabilization work focused on the stone masonry foundations in front of the cavates.

Stabilization work began in Frijoles Canyon with Hewett, who also pursued reconstruction, who reconstructed the masonry entrance to Cave Kiva, a very large cavate located in Group E in 1910. At Group D in 1908, Hewett excavated and stabilized wall foundations to evoke the tiered, multi-story complex of masonry buildings that once stood against the north wall of Frijoles Canyon.

Extensive stabilization work in the cavates began with R.H. Lister, whose work took place between 1939 and 1940, when he stabilized 26 cavates in Frijoles Canyon by replacing the mortar and chinking stones in the masonry, and constructed 46 water diversion dams to protect cavate openings. He did much of his work at Long House, as well as in Groups A, B, F, I, K and M, and also worked at Tsankawi, Otowi, Pueblo Canyon and along the Rito de los Frijoles. Lister located 567 cavates outside of Frijoles Canyon, and worked on more than half of them. Much of his stabilization work entailed building dams at cavate entrances or modifications above them to prevent water from running into and through the cavates. He also repointed some masonry walls in Frijoles Canyon, using mud mortar and chinking stones<sup>19</sup>. Toll considers this work to be fairly

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<sup>19</sup> Mary Slater, Bandelier National Monument, personal communication with the author, January 23, 2001.



successful, as a result of visual analysis. Lister performed mostly masonry stabilization at Long House, but did work inside the cavates there as well.<sup>20</sup>

Lister supervised the stabilization work that took place around cavate M-100. Although he did not record the room numbers of those cavates that he stabilized, he did document photographically the work he did. There are photographs of several of the cavates around M-100, but none of M-100 itself. Lister performed such stabilization tasks as “remortaring and chinking” with mud mortar and presumably local bits of stone, as well as attempting to stabilize the eroding cliff face. He and his crew cut slots into the cliff face, and placed stones into them in order to stabilize the cliff face. He also reassembled a masonry wall that had fallen in one cavate, using both original and replacement stones.<sup>21</sup>

In conjunction with his excavations, Hendron also performed stabilization on cavates within Group M, beginning in 1943. He excavated five rooms and four “caves”, numbering them 1, 2, 3, 4, and 5 and 1, 2, 3, 4, respectively. In his report, Hendron describes more about his excavations and the possible construction techniques employed by the Ancient Puebloans than of his stabilization work. However, it can be inferred that he carried out similar work to that of Lister. He and his crew did reconstruct a side wall on Room 1 (M-99) and a front and side wall on Room 2 (the side wall was shared by the two rooms).

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<sup>20</sup> *The Bandelier Archaeological Survey, Volume 1*. Robert P. Powers and Janet D. Orcutt, eds., (United States Department of the Interior, 1999), p.11.

<sup>21</sup> *Stabilization of Frijoles Cave Ruins*, Robert H. Lister. Coolidge, AZ: Southwestern Monuments Headquarters, National Park Service, USDI, 1940, p.43-59.



Hendron numbered M-100 "Cave 1", which he describes as placed directly above Room 1. Hendron speculates that M-100 was entered from the roof of M-99, stating that "indications were that the cliff surface was sufficiently eroded to have removed all traces of viga holes for a second story room if there was a second story which is not likely."<sup>22</sup>

Hendron records the dimensions of M-100, which he calls "the best preserved cave of the entire group", as rectangular in form, seven feet wide by eight feet long, and the entrance as four feet four inches wide and three feet nine and three-quarter inches high from the floor.<sup>23</sup>

Hendon's stabilization work included repointing masonry and capping friable tuff surfaces with concrete, although he does not mention exactly which cavates he performed work on.

John Francis Turney worked with Hendron during the 1943 campaign, and subsequently wrote his Master's thesis on the analysis of the material collected during this campaign. He states in his foreword:

The central section of Group M of the Cliffs was exposed to an excessive amount of weathering and erosion. The walls were falling and were badly in need of repair. The cliff surfaces were also wearing away and leaving the cave rooms subject to further damage. For these reasons a program was actuated on the thirty-first of May, 1943, for the repair and stabilization of Group M.<sup>24</sup>

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<sup>22</sup> *Group M of the Cliff Dwellings: Rooms 1, 2, 3, 4, and 5, Caves 1, 2, 3, 4, Frijoles Canyon, Bandelier National Monument, New Mexico.* J.W. Hendron, 1943, p. 22.

<sup>23</sup> *Ibid*, p.22-23.

<sup>24</sup> *An Analysis of the Material Taken from a Section of Group M of the Cliffs, Frijoles Canyon, Bandelier National Monument, New Mexico, 1943.* John Francis Turney, A.B. Master of Arts Thesis in Anthropology, Adams State College, Alamosa, Colorado, 1948, n.p.





Turney also does not mention which cavates stabilization was performed on. It is assumed, however, from descriptions given, that they did not perform any stabilization on M-100. The cavates around M-100 all have associated masonry walls forming their entrances. These walls are given some attention, and are similar to the walls that Lister would have stabilized. M-100, however, does not have one of these walls, making “remortaring and chinking” unnecessary.

In 1974 the floor of Cave Kiva was recapped with concrete and the masonry entrance rebuilt. Replastering the walls and resmoking the ceiling obscured graffiti in Cave Kiva. Capping the floors with concrete stabilized other cavates in Group E that the public is allowed to enter via wooden ladders.

#### **1.4 Site Preservation and Presentation**

##### *Preservation*

The preservation of the more than 1,200 cavates at Bandelier is, and always has been, the primary mission of the Park. These unique resources have been recognized as treasures by the Pueblos of New Mexico, the state of New Mexico, and of the nation. They are a highly vulnerable resource, and the complex geology that led to their formation also led to their current fragile state.<sup>25</sup>

Until recently, preservation of prehistoric sites in the Southwest has focused on modifying structures through standard methods of stabilization and reconstruction. The work was usually accomplished by archaeologists

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<sup>25</sup> Mary Slater, “Bandelier National Monument Cavate Pueblos on List of New Mexico's Most Endangered Historic Places,” Draft Press Release, 2001.



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and field crews trained by archaeologists. Now, Bandelier National Monument is approaching site preservation through hiring conservators, and by working with natural and cultural resource professionals to implement treatments based in research and specific to their unique environment. Most of the recent conservation study work on the cavate pueblos has taken place at Tsankawi, a detached section of Bandelier National Monument that has the second highest concentration of cavates in the park. From 1997-1999 the Architectural Conservation Laboratory at the University of Pennsylvania Graduate Program in Historic Preservation and Bandelier National Monument conducted pilot plaster stabilization and graffiti mitigation treatment testing, as well as design and testing of a condition assessment methodology for cavate pueblos. In 1998 the University of Pennsylvania conducted a Trail Preservation Study, which included petrographic analysis of samples of the Tschirege and Otowi Members of the Bandelier Tuff. In 1999 the National Park Service continued testing graffiti mitigation and also laboratory and field tested methods of reattachment and edging of earthen plasters on tuff. The conservation work completed at Tsankawi is a source of information and guidance for work in Frijoles Canyon.

The current Cavate Preservation Program at Bandelier National Monument consists of three goals:

- “1. to identify, document, conserve and maintain cavate resources as both constructed and natural heritage;



2. to develop a comprehensive and culturally adaptive conservation and management program for Native American heritage sites focused on culture, tradition, and appropriate technology;
3. and to train and develop professional skills of Native and non-Native students and other professionals in preservation technology.”<sup>26</sup>

### *Presentation*

The United States Forest Service (USFS) managed Bandelier National Monument until 1932, when it was transferred to the National Park Service (NPS) who began regulating visitor use of the area, including the cave pueblos in Frijoles Canyon. The NPS developed the Monument as a destination for visitors through the Emergency Conservation Work Program, where Civilian Conservation Corps (CCC) workers built a road into Frijoles Canyon and built an administrative area and lodge in the canyon from native materials. (Their work comprises the CCC Historic District in Bandelier National Monument, which was declared a National Historic Landmark District in 1987.) After World War II the Atomic Energy Commission became an important presence on the Pajarito Plateau. Scientists developing nuclear weapons in nearby Los Alamos came to Frijoles Canyon for relaxation, and the lodge hosted preeminent nuclear physicists of the time. Today Bandelier National Monument has expanded to 32,817 acres, and the National Park Service continues to administer the park from its headquarters in Frijoles Canyon. The cave pueblos in Frijoles Canyon are the main attraction at the

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<sup>26</sup> Scope of Work, Cave Preservation Program, University of Pennsylvania.



park, and visitors get a close look at over 200 cavates along the main trail.

The remaining 800+ cavates are closed to public access.<sup>27</sup>

The primary theme of interpretation at Bandelier National Monument has been the continuum of the Rio Grande Puebloan culture, including the early periods to the north and west, the developments on the Pajarito Plateau and through to the present-day Pueblos. The more recent, secondary themes have placed emphasis on natural history, the wilderness, feral animal management, endangered species, fire ecology, local geology, energy conservation, the National Park ideals, and ecology.<sup>28</sup>

In the past, reconstruction has served as a method of interpretation. At Group E, Kenneth Chapman reconstructed 4 masonry rooms in 1920 to serve as replicas interpreting the original masonry and cavate configuration of the cliff pueblos. Another replica was built in 1910, when Jesse Nusbaum reconstructed a semi-subterranean kiva in a small cavate pueblo called Ceremonial Cave, located in a remote alcove 140 feet above the Frijoles Canyon bottom.<sup>29</sup>

In 1934 Paul Reiter of the School of American Research exposed a decorative mural painted on earthen plaster in Group D and covered it with a glass plate.<sup>30</sup> Mary Slater replaced the glass plate during the summer of 2000.

Today, Bandelier National Monument is open 363 days a year for a minimum of 8.5 hours per day. The Interpretive staff conducts scheduled

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<sup>27</sup> Angelyn Rivera, Bandelier National Monument, personal communication with author, April 11, 2001.

<sup>28</sup> *Bandelier—A Brief Why and When*, Bandelier National Monument handout.

<sup>29</sup> Angelyn Rivera, Bandelier National Monument, personal communication with author, April 11, 2001.

<sup>30</sup> Ibid, April 11, 2001.





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tours along the self-guided trail highlighting the Ancestral Puebloan habitation in Frijoles Canyon. Access to restricted areas may be given through a special permit granted by the Superintendent of Bandelier National Monument.

The Monument has an agreement with the residents of the Pueblos of San Ildefonso, Santa Clara, and Cochiti, whose oral histories reflect an ancestral presence in areas currently managed by the Monument: members of these three Pueblos may enter the Monument free of charge. Bandelier National Monument plans to extend a similar offer to the remaining affiliated Pueblos of San Felipe, Santo Domingo, and Zuni. Commercial tours are conducted through seventy-four vendors located in Santa Fe and surrounding communities.

Bandelier encourages visitation from affiliated tribes that have tribal, religious and cultural interests. Special interest groups who would like to study the caveate pueblos and contribute to a fuller understanding of the architectural and cultural significance of the resources are also encouraged to visit and use the park. Special interest groups include university students and faculty, State Historic Preservation Staff, and other federal employees involved with historic and ancestral preservation and heritage management.<sup>31</sup>

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<sup>31</sup> Angelyn Rivera, Bandelier National Monument, personal communication with the author, April 11, 2001.



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## Chapter Two

### CAVATE ARCHITECTURE AT BANDELIER NATIONAL MONUMENT

As previously noted, cavates are an extraordinarily fragile archaeological resource. They contain delicate architectural features, earthen finishes and embellishments incised into these finishes. Deterioration, both natural and humanly-induced, poses a threat to the stability of these structures and their associated features. Documentation is a necessary and practical method of providing baseline monitoring, as well as data to develop conservation strategies.

This chapter explores the efficacy of digital documentation for cavate architecture, by using one cavate, M-100, as a model condition assessment project. Three different software applications are used in conjunction to provide an accurate, useful description of the space as well as a set of annotated drawings to be used in conservation planning for the cavate.

#### 2.1 Frijoles Canyon

Frijoles Canyon was a densely settled area between 1300 and 1600 C.E. Hewett separated the cavates in Frijoles into 13 groups, A through M, based on breaks between the clusters. These breaks are frequently caused by natural drainages or stretches of cliff unsuitable for cavate construction. The groups vary in size and number, and whether they represent 14 or more different settlements as implied by the grouping is unclear.<sup>32</sup> (*See Figure 3*)

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<sup>32</sup> Ibid, p.17.



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## 2.2 Group M

Group M is located on the north side of Frijoles Canyon, behind the residential area, and is closed to the public. It sits at the top of a steep talus slope, and is a large, continuous group of cavates and masonry structures. (See *Figures 7 and 8*)

Group M was mostly constructed and occupied during the period between 1325 and 1600, known as the Classic Period, according to Powers. Aggregation of population in the canyon had begun prior to this period, but continued throughout the 1400s. This was a regional trend, and until the sixteenth century much of the population of the Pajarito Plateau was concentrated in less than a dozen large pueblos. The occupants of Frijoles Canyon, and the surrounding Pajarito Plateau, were part of the Puebloan society found in the region, including places such as Mesa Verde and Chaco Canyon.<sup>33</sup>

Agriculture during this period appears to be similar to agricultural methods in preceding periods. The lack of irrigation features and geographic dispersion of field sites indicates that individual families using non-hydraulic methods were responsible for the majority of agricultural production. Trade during the period involved an assortment of subsistence and ceremonial items, including ceramics, chipped stone, cotton, turquoise, and presumably a large number of perishables. On the whole, this period was the beginning of increasing social complexity<sup>34</sup>

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<sup>33</sup> *The Bandelier Archaeological Survey, Volume 1*. Robert P. Powers and Janet D. Orcutt, eds., (United States Department of the Interior, 1999), p. 26.

<sup>34</sup> *Ibid*, p.26-27.



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There are several dates given for the onset of occupation of Group M.

Both Kohler and Powers suggest that occupation began in the Early Classic Period (1325-1375), followed by a hiatus and reoccupation in 1440, the Middle Classic. Toll disagrees, asserting that occupation did not take place at all in the Early Classic, beginning instead in the Middle Classic. All parties agree that occupation lasted through the Late Classic, until at least 1600. There is also speculation, due to the embellishments and ceramics present, that this group was reoccupied during the Pueblo Revolt Period (1680-1692). (See Figure 4)

Group M is clearly defined by large natural drainage cuts at either end, and is divided into two smaller sections, Upper and Lower. Upper Group M, which includes structures 1 through 67, is the western half of the group, and includes approximately 140 of the total 204 cliff-associated rooms in the entire group.<sup>35</sup>

The talus slope at the upper end of the western half of Group M (rooms M-3-M-14) is very steep, and the flat portion at the top is very narrow. No evidence of masonry rooms exists here today, but they were most likely present during occupation. As one moves toward the opposite end of this half of this group, the flat areas grow wider, and there are many suggested walls and strewn blocks present. It is in this area that it is possible to see three levels of rooms. Wall

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<sup>35</sup> H. Wolcott Toll, *An Analysis of the Variability and Condition of Cavate Structures in Bandelier National Monument* (United States Department of the Interior, 1995), p. 45-51.





alignments around M-35 – M-49 suggest as many as three rows of rooms extending out from the cliff face.<sup>36</sup>

Lower Group M (M-68 – M-163), the eastern half, was best documented in Hendron's excavations of the early 1940s. This area of Group M was not investigated by Toll, but he did note some prominent features, including several exposed hearths, a potential kiva, and the embellishments throughout the entire group. Almost all of the embellishments occur inside the cavates, and include incised figures; white, red, yellow, and black wall paintings; and plaster finishing.<sup>37</sup>

### 2.3 Cavate M-100

Cavate M-100 is located in the eastern half of Group M, on the east edge of a cluster of several cavates and masonry structures. It is a large cavate, on the second tier of rooms. There was a small masonry room (M-99) on the first tier in front of it, however all that exists of that room today are remnants of the east and west walls. (*See Figure 5*)

M-100 is a fairly large, rectilinear cavate, with very high architectural integrity. The walls are plastered to the top, and overlap slightly on to the flat ceiling. It is 1.84 m high in the center, making it possible to stand fully upright, and 2.57 m deep, and 2.19 m wide. The walls taper in slightly toward the top. The ceiling is also rectilinear and is completely sooted tuff, and has a large

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<sup>36</sup> Ibid, p. 51.

<sup>37</sup> Ibid, p. 51-52.



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diagonal groove running diagonally, measuring 0.10 m deep. There are two niches in the cavate, one on the north (rear) wall that is 0.21 m high and 0.37 m wide, and a shallow floor niche on the east wall, measuring 0.79 m high and 0.10 m deep. There is a firepit in front of this niche. There are also two depressions in the rear corner of the west wall, possibly the result of foot abrasion associated with the kneeling position used for grinding corn. These two depressions together measure 1.03 m across. There are also two smoke holes on the south elevation, above the entrance.

There are several campaigns of earthen architectural finishes visible on the walls, at various heights. The most recent campaign is a tan wash on the walls, along with a modified black soot wash over the tan at the embellishment level, mid-wall. This black soot wash is applied over the upper zone of the most recent dado, approximately 0.55 m above the floor. The present finish scheme, as well as potential past schemes, will be discussed in depth in the following chapters.

During the field investigations, three wall ridges were found in the cavate. Located on the east, west and south walls, each ridge stops at the height of the ceiling. These ridges are not attached to the walls, but are raised off the wall with a hollow beneath. What purpose do these ridges serve? Do they define activity areas in the cavate?

Also investigated at length were the finish campaigns. Three horizontal dado lines were found, differing in height and period. The highest dado (Dado C) is the earliest of the three, and is 1.06 m from the floor. The second dado (Dado



B) is 1.04 m from the floor, and Dado A, the most recent dado, is 0.91 m from the floor. This sequence is visual evidence that the dado changed in height over time—becoming lower or smaller in height—and the appearance of the cavate changed with it. The most recent campaign includes a tan dado (A) rising at least to the floor of the niche in the north wall, but probably extended above and around the niche in an aura. Areas of deterioration provide a hint of earlier campaigns. Visible in areas throughout the cavate is a gray finish underneath the present scheme.

One of the most intriguing elements of the cavate are the many embellishments present, and the presence of what appears to be a partial black wash. Sooting on the walls and ceilings of the cavates is a common feature, and it has been previously assumed that this sooting is the direct result of burning, presumably from hearth-fires within the cavate. However, cavate M-100 provides evidence that the last layer of soot, at least on the dado on the walls, has been manipulated as a black wash rather than simply as airborne deposition.

The ceiling of M-100 is sooted, as are the walls. The soot deposited on the ceiling however has an orange peel-like texture, very thick, rough and granular. The soot on the walls has a very smooth, uniform texture. This black layer begins about 0.55m from the floor of the cavate, in the upper zone of the most recent dado. There is a distinctive splash pattern at the juncture of the clean tan dado and the black above it, indicating that the method of application was wet. If this was merely soot deposition as a result of burning, the soot would appear both above and below the tan dado, not simply stop in the middle. Also



visible in the black wash is evidence of the application method—the layer is striated, indicating that it was manipulated rather than simply deposited. The direction of striation is horizontal on the dado, and vertical above. This pattern of black on top, tan below appears on all of the walls, but it is rubbed off over the hearth, or never applied at all.

Another indication that the black was washed on intended to be a surface finish is the presence of embellishments at this level. The embellishments are incised into this black wash, suggesting that the black was deliberately applied and the embellishments were incised after the application to expose the tan color of the dado wash below. This method resulted in a stark contrast between the lighter tan dado and the black wash, making the embellishments stand out.

How this black wash was produced is unknown. It is possible that the occupants simply wetted the deposited soot on the wall above and smeared it down, creating their wash. It is also possible that they produced it separately and applied it, in a process similar to how they might have mixed and applied the other washes in the cavate. There is a distinctive splash pattern, presumably a result of the application of this wash, on the tan dado below.

There is evidence in the last finish campaign that is indicative of a very late occupation or reoccupation of the cavate. Included in the embellishments are horses and a figure suggestive of Catholic iconography. Both of these figures are Spanish introductions to North America.

There is no visible indication of sooting on the tuff prior to the application of the first plasters. This is corroborated by the thin section analysis. There is,





however, soot deposition on the rock in areas of substantial loss. A greasy brown staining accompanies this deposition on the rock, and is also evident on the ceiling, where the soot was deposited continuously over the entire occupation. The soot deposition on the exposed rock is another indication that the cavate was abandoned and reoccupied; or simply that the loss of surface finishes during occupation went unrepaired. Given the number of finish layers, it is likely that the sooted tuff reflects reoccupation instead. This loss and reuse provides credibility, along with the presence of the horse figure, Catholic-influenced iconography, and artifacts to the theory that the cavate was reoccupied briefly during the Pueblo Revolt Period.

## **2.4 Documentation and Recordation**

### *2.4.1 Methodology*

#### Field Investigation and Recordation

Bandelier National Monument, jointly with the University of Pennsylvania Graduate Program of Historic Preservation, conducted a field school in June 2000. The school was a field exercise in site conservation and heritage management, and the month was spent undertaking a conditions assessment of cavates in Groups C, D and E, as well as graphic conditions survey and graffiti mitigation for several pre-selected cavates, including M-100. The four cavates chosen for graphic conditions survey were selected because of their high integrity.



The first step of survey was to prepare a condition assessment form for the space. The objectives of this survey were to identify and describe the existing architectural fabric; to record the condition of the cavate and its features as a baseline for monitoring and planning future conservation work; to identify threats to the current condition and integrity of the resource; to determine treatment urgency and recommend treatments; and to provide information needed to prepare a long-term preservation and management plan for the cavates.<sup>38</sup> (See Figure 6)

Information included in the condition assessment form consists of group, room number, date, surveyor, plan type, context, exposure, dimensions, a plan and section, building materials, features, finishes, evaluation of existing conditions, treatment recommendations, and so forth. An example form, as well as the associated field handbook, is included in Appendix A.

M-100 is rectilinear in shape, facing southwest. It is a protected space, with an eroded entrance spanning 1.33 m high and 1.38 m wide. The cavate is excavated from Tschirege tuff, and features include a firepit, large floor level niche, wall niche, slot, possible loom anchors, smoke hole, vent, sooted ceiling, metate rest, and upper loom supports.<sup>39</sup> The surface finishes are earthen plastered walls and a sooted rock ceiling, the walls display several layers of

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<sup>38</sup> Condition Assessment Form, Site Conservation and Heritage Management Field Program, Bandelier National Monument, Los Alamos, NM, 2000.

<sup>39</sup> All feature terminology for the condition assessment was taken from H. Wolcott Toll, *An Analysis of the Variability and Condition of Cavate Structures in Bandelier National Monument* (United States Department of the Interior, 1995).



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applied plaster and wash finishes. The finish visible are brown, tan and black, and numerous incised embellishments are present.

The next step in the detailed recordation of M-100 was a graphic conditions survey. Conditions were recorded on 8x10 black and white photographs. The photographs represented a partial elevation of a wall within the cavate. Using a color-coded graphic system, the conditions present in were recorded on an acetate sheet over the photograph. Conditions recorded were: architectural features; biological growth; color change; finish, map- and masonry-cracks; embellishments; displacement; graffiti; mechanical damage; surface deposits, including animal and carbon deposits; surface salts; loss; partial loss; detachment; disaggregation; delamination; blistering; vegetation; and additional notes (See also Appendix A for glossary of conditions).

#### *2.4.2 Digital Documentation*

Several different digital techniques were utilized to delineate the space and the conditions. These digital techniques utilized Adobe Photoshop 5.5<sup>®</sup>, AutoCAD 2000<sup>®</sup> and AutoCAD Overlay 2000<sup>®</sup>.

##### *Photoshop 5.5<sup>®</sup>*

The photographs used in the graphic conditions survey were already available in digital form, and provided by Bandelier National Monument for digitization purposes. These photographs were assembled into a photomontage of the space, initially as one continuous rollout, and then broken down into individual walls.



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To produce a photomontage, the photographs were opened in Photoshop 5.5<sup>®</sup>. The size of the images was adjusted and each photograph was imported into the new background layer as a separate layer. This allows manipulation of each image separately (move, adjust levels, etc.) while seeing all other images as well.

Using the different options available for image manipulation, each photograph was optimized to make as many features and embellishments as clear as possible. These manipulations consisted primarily of adjusting the brightness and contrast of each photo, as well as the levels.

Using known features in each photograph, each layer was matched to its adjacent photograph. This overlap of areas in photographs is essential for the graphic conditions survey, as well as this process. It is suggested that each wall be montaged as an individual wall, rather than all walls together. It is necessary to manipulate the image further during this process, as often they do not match up perfectly.

Further image manipulation is necessary when the images are in place. Not all photographs look the same, making the boundaries of each image visible. To blend the images together, there are several tools that can be used. Brightness and contrast can again be adjusted to a certain extent, as well as the levels. Most useful here were the burn and dodge tools. These tools allow one to either lighten (dodge) or darken (burn) the pixels of the selected area within a selected layer, at a selected exposure. These tools allow one to blend the lines of the photographs out, ideally creating a seamless image. A seamless image is





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not always possible, however, as the exposure of some photographs differs greatly. It is possible to bring them close to each other, though, and create a clean image.

Once the photographs have been adjusted and blended to a satisfactory point, the layers can be flattened, or made into one image rather than a number of layers.

### *AutoCAD Overlay<sup>®</sup>*

Once the photomontage has been flattened, it can be imported into AutoCAD Overlay<sup>®</sup>. To digitize the conditions collected in the field, layers must be created. The colors and patterns had been pre-selected for the digitization of M-100, based on a system being used at the University of Pennsylvania's Graduate Program in Historic Preservation C.A.S.P.A.R. project at Mesa Verde. Reds generally represent subtractive conditions; greens, additive conditions; black and grays, cracking and displacement; and blues, repairs. Some of these colors were modified for the survey of M-100. Since a large part of the surface of M-100 is black, some colors did not register. These were changed as necessary, but intended to stay within the original system.

For more than one condition using the same color, it is recommended that different shades of that color be used. For example, since all subtractive conditions are red, a different shade of red was used for each one. AutoCAD Overlay<sup>®</sup> has a color palate and number system for colors, which allows the user to select various shades and keep track of which colors have been used. It is also suggested that the hatch patterns for each condition be cut and pasted into



separate layers. That way the hatch layers can be turned on and off if necessary, increasing the readability of the drawing.

### *AutoCAD®*

The actual conditions are digitized using AutoCAD® tools. This is the most time consuming, yet technically simple, part of the process. Each area of each condition in its individual layer is outlined in polylines, which must be closed. This closed area is then hatched in with the specified pattern.

## 2.5 Annotated Drawings

Annotated drawings are the end result, and ultimate goal, of the above process.<sup>40</sup> Relationships between conditions can be analyzed visually through this process. These drawings can be used for interpretation in various ways. For instance, they can be used to calculate the area, in m<sup>2</sup>, of the individual conditions.

Condition	Area in m <sup>2</sup>	%
Total Surface Area	20.5938 m <sup>2</sup>	
Total Interior Surface Finish	12.9466 m <sup>2</sup>	
Total Wall Surface Area	16.4476 m <sup>2</sup>	
Ceiling Area	4.1462 m <sup>2</sup>	
Loss	3.1745 m <sup>2</sup>	19% of finish remaining
Partial Loss	2.9771 m <sup>2</sup>	18% of finish remaining

<sup>40</sup> See Appendix B for annotated drawings.



Delamination	3.2878 m <sup>2</sup>	20% of finish remaining
Detachment	3.0789 m <sup>2</sup>	18% of finish remaining
Map Cracking	1.4481 m <sup>2</sup>	8% of finish remaining
Surface Carbon	11.8902 m <sup>2</sup>	72% of finish remaining
Biological Growth	0.3451 m <sup>2</sup>	2% of finish remaining

Table 3.1

As you can see in the table above, loss and delamination are the largest subtractive conditions present in M-100.

### *Subtractive Conditions*

#### *Total Loss*

Total loss is defined as the absence of original material, in this case rock or finishes, in areas, and/or the loss of finishes to the rock from within the boundaries of a moderately- to fully-intact finished area.<sup>41</sup> There are several large areas of loss present in M-100, totaling 3.1745 m<sup>2</sup>, or 19%, of the cavate. The most evident areas of loss are adjacent to the south, near the entrance to the cavate, on both sides. Frijoles Canyon experiences heavy rain in the summer, as well as snow in the winter, which are a potential cause of loss in this area. Driving rain or snow would cause substantial deterioration, causing wet/dry cycling, leading to delamination and loss. Wind abrasion could also contribute to loss through mechanical abrasion. Without the closure of the opening, which presumably occurred during occupation, the result would be severe deterioration, which can be seen. There is minor loss present on the top of the inner wall

<sup>41</sup> See Appendix A for definitions of conditions.



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above the entrance, where precipitation is not as likely to come into direct contact due to the small size and angle of the opening.

The loss in the rear of the cavate, particularly on the north wall, is more difficult to explain. It is possible that thermal expansion, due to solar radiation, is a cause of deterioration. There is potentially enough direct light entering the space, through the entrance or the smoke holes, to cause the extensive damage found on the north wall. There are also isolated areas of loss on the east wall, which could potentially be the result of thermal deterioration.

Freeze/thaw is another potential reason for the loss occurring in M-100. Freeze/thaw cycling in the presence of moisture can stress a material's strength. The mechanical stress induced by entrapped moisture crystallizing can cause significant failure.<sup>42</sup> Moisture trapped between layers of plaster and the presence of salts could also result in severe loss. There are natural chlorides present in the stone, and any moisture present could activate them. The crystallization of salts between layers of plaster could lead to delamination, blistering or detachment.

### *Partial Loss*

The areas of partial loss, defined as the loss of one or more finish layers from the existing finish, leaving earlier layers exposed, covers 2.9771 m<sup>2</sup>, or 18%, of the total finished area of the cavate, and is directly adjacent to and surrounds areas of loss. This is indicative of an active condition, eventually

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<sup>42</sup> *Trail Preservation Study, Tsankawi Mesa, Bandelier National Monument, Los Alamos County, NM, National Park Service, USDI.* Prepared by Frank G. Matero, T. Scott Kreilick and Gomaa I. Omar, January 1998-May 1998, p. 123.





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resulting in total loss in those areas. Partial loss between layers could be a result of a number of factors. One hypothesis is that the earthen finishes do not form a good adhesive bond with contiguous layers due to the layer of soot deposited between them, resulting in the delamination and partial loss.

### *Delamination*

Delamination, or flaking, is the separation and lifting of discrete layers of finishes from each other. The areas of delamination surround the areas of total loss throughout M-100, resulting in a 3.2878 m<sup>2</sup>, or 20%, area. Delamination and partial loss also overlap in most areas. These three conditions seem to be directly related to one another, making delamination the primary cause of total loss in M-100. Freeze/thaw cycling could be a direct cause of delamination. Trapped moisture between layers of plaster or thinner washes freezing and expanding would cause damage resulting in the delamination of layers. It is also possible that the earthen finishes, when applied, did not form a good adhesive bond with one another due to the greasy carbon soot layers present between each layer. As a result of this insufficient bond, the finishes are delaminating at the point of contact with the soot layer. This phenomenon is visible in thin section. The samples break horizontally at the intersection of the finish and the soot deposits.

This offers an explanation of the overwhelming presence of delamination, as well as loss, over the lower sections of the walls. It can be presumed that the thinner layers of finishes are the weakest. The weaker layers would be the most affected by the freeze/thaw phenomenon, as well as by the weak bond with the



soot. These would be the first to delaminate, and the first to show evidence of major loss, while the thicker layers higher on the walls would be more stable.

### *Detachment*

Detachment is voids between finish layers, at the rock/plaster interface, or within the rock, which have visible detached edges and which are not necessarily confined to discrete layers as in delamination. Detachment is also related to loss and delamination in the cavate, although the worst area of detachment is located on the north wall. This area totals  $1.9 \text{ m}^2$ , or 50%, of the total  $3.8 \text{ m}^2$  of detachment present in M-100. This area does surround an area of total loss, however it extends beyond simply being related to this condition. It is unclear why detachment is so much more prevalent on this wall than in the rest of the cavate. It could be a result of several phenomena: freeze/thaw; weak adhesion between the finish and the soot; and wind driven rain or snow blowing in the opening and hitting this wall and wetting it, causing the upper layers of finish to detach; or moisture percolating through the wall from above. The area of total loss on this wall is disaggregating, indicating that this situation is a strong possibility.

### *Cracking*

Cracking, and map cracking in particular, seem to be related to both delamination and detachment. The sole area of map cracking on the north wall,  $0.60 \text{ m}^2$ , directly overlaps the largest area of detachment in the cavate. The largest area of map cracking, on the east wall,  $0.5994 \text{ m}^2$ , overlaps with the largest area of delamination. The other areas of map cracking also overlap areas of delamination. Nearly all the map cracking, as well as the finish cracking,



is located on the lower half of the cavate. The map-cracking present in the finish layers could have occurred shortly after application, during the drying process, when the finish shrank as it lost water and cracked. It could also be the result of the wet-dry process, from moisture in the form of rain or snow entering the cavate and wetting the walls, causing the layers to expand and shrink.

### *Additive Conditions*

#### *Surface Carbon*

Carbon deposits cover much ( $17.12 \text{ m}^2$ ) of the cavate. The ceiling area accounts for  $4.1462 \text{ m}^2$  of this total area. It is thought that these deposits are the intentional result of fire burning inside the cavate. As previously noted, tuff is an extremely friable rock. One theory regarding the sooting of cavates is that the soot sealed the rock, preventing rock dust from contaminating the cavate space. In the case of M-100, this theory would apply to the ceiling only, as washes and plasters cover the unsooted tuff walls. There are carbon layers present between layers of washes and plasters as well, indicating that sooting was a repetitive process. As the last finish, soot wash also seems to have been applied to the lower sections of the walls, as there is a striated pattern visible in the soot wash present on this section today, and a distinct drip pattern below. The texture of the soot layers on the upper walls and ceiling is very granular, while the soot present in the lower sections is very smooth.

#### *Biological Growth*

Biological growth—the presence of micro flora, i.e. algae, fungi and/or lichen, on the surface—is not a severe problem in M-100. There are four isolated areas of growth in the cavate: one by the entrance on the west wall; one small



one above the entrance on the south wall; one tiny spot on the north wall; and one on the east wall. These four areas comprise only 0.35 m<sup>2</sup>, or 2%, of wall surface. All of the growth is in areas of total loss; presumably areas where water and light exist.

### *Embellishments and Graffiti*

Embellishments, in the case of M-100, are occupation-period incised designs in the plaster and wash finishes. Graffiti, on the other hand, is historic defacement of the space, usually in the form of names etched into the walls. It is interesting to note the placement of both of these phenomena. Visible embellishments occur largely below the line of Dado B, while graffiti, for the most part, occurs above Dado C. It is possible that embellishments and graffiti are applied in the zone of occupation. The zone of use of the original occupants seems to have been at a sitting level, while the zone of use for later visitors appears to have been at a standing level. The embellishments in the cavate are extremely fragile, and their permanence is threatened by the continual loss of the finishes in the cavate. They occur primarily in the lower areas of the cavate, where partial loss, delamination and detachment are the principle problems. The embellishments are incised into these finishes, and are lost as the finishes are lost.

### *Disaggregation and Map Cracking*

There are several additional active conditions present in Cavate M-100. Disaggregation is present in areas of total loss. It is likely that the tuff is absorbing water by capillary action in areas exposed to the elements, resulting in the disaggregation of the naturally friable tuff. Map cracking is also present in the





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cavate, probably as a result of wet/dry cycling. The locations of map cracking pinpoint the areas where water is entering the cavate. Map cracking is associated with delamination in the areas of M-100 exposed to the weather.

## **2.6 Comparison with Historic Photographs**

Current photographs were compared with historic photographs taken between 1916 and 1951.<sup>43</sup> While there are small areas of partial loss evident today that were not present between these years, no severe deterioration has taken place inside Cavate M-100 during the past 85 years. There are two, possibly three, areas where embellishments have been lost, partially or entirely. The loss of these embellishments took place between Chapman's survey of 1916 and Steen's survey in 1943. The direct cause of this loss is unknown, however it can be assumed that delamination, detachment and partial loss have affected those areas of finish.

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<sup>43</sup> See Appendix C for comparison of historic and current photographs.



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### Chapter Three

#### Interior Finishes Analysis and Characterization of Cavate M-100

One goal of this investigation was to develop a possible typology of finishes, based on morphology, composition and location. Thickness was considered a critical attribute that might differentiate function. “Plaster” and “wash” were terms considered based on finish thickness. Plaster is defined as “A composition of a soft and plastic consistency, which may be spread or daubed upon a surface, as of a wall, where it afterwards hardens”<sup>44</sup> A wash is defined as “A thin coat of water-colour or distemper spread over a wall or similar surface.”<sup>45</sup> These definitions suggest viscosity and body as key factors in differentiating a plaster from a wash. The definition of a wash applied at Mesa Verde National Park is anything under 1 mm in thickness, and anything over 1 mm in thickness is considered a plaster.

Another objective of this chapter is to characterize the composition of the earthen finishes used in Cavate M-100. for reasons both in conservation and archaeology. What were the people of Frijoles Canyon using to finish their spaces? Where did the materials come from? Can we find these materials and use them today to conserve the finishes? While this chapter does not attempt to answer these questions directly, it does provide a starting point-. Knowing what an architectural finish is constituted of—its matrix and aggregate—is of essential importance in making appropriate conservation decisions.

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<sup>44</sup> *The Oxford English Dictionary*, definition II, 2a. [www.oed.com](http://www.oed.com).

<sup>45</sup> *Ibid*, definition II, 4d.



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The standard methodology applied in this research is based on the physical analysis of samples collected from Cavate M-100. The samples were examined at macro and micro morphological levels to characterize the finishes to the greatest possible extent. Microscopy was employed as the primary method of examination.

Observation of the macro morphology of the sample stratigraphies illustrates the sequence of finishes employed in the space through time, as well as the potential to observe individual design schemes at specific times. The micro morphology of the samples provides evidence of the physical properties of the finishes, including their compositions and manufacturing processes through examination of the matrix and aggregate.

Another purpose of the investigation was to record the basic characteristics of the earthen architectural finishes in the cavate, including color, (of the layer as a whole and the matrix and aggregate individually), coarse to fine ratio, particle shape, and surface texture. This was done using light microscopy, with the intent of providing a base characterization of the materials used.

Field investigation took place in June 2000 and December 2000. During this time M-100 was visually examined in reference to architectural details, finish campaigns and recorded.

### **3.1 Sampling**

Sampling methods depend on the type of study envisaged. In this particular study, the goals were:



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1. to determine the presence, absence and variation of finishes throughout the cavate and over time;
  2. the composition of the finishes;
  3. the decay mechanisms and performance characteristics.

19 samples were taken from Cavate M-100.<sup>46</sup> One sample was taken of the tuff, two of the ceiling, two of the floor finishes and 14 samples were taken of the finishes on the walls of the cavate. Samples were taken from each of the four walls, aiming to be a representative from each wall in a vertical manner to capture the full stratigraphy of each section. The samples were chosen by visually determining where changes and patterns may have occurred. Three visible changes in the dado height were found, and samples were taken to acquire a representative sample of all three. Samples were also taken near architectural features such as the wall ridges and niches.

Thirteen samples were taken initially. Basic analysis was performed, using thin sections, to determine layer structure. This was done to gain the best picture of where further samples were needed. In areas that were not fully represented, more samples were taken, samples 100.14 through 100.19. Both 100.14 and 100.19 were taken to verify 100.08, and the comparative results were unexpected. 100.08 and 100.14 are very similar, with only two layers, while 100.19 has 40 layers. Sample 100.18 was a tuff sample taken to test the rock for salts.

Samples were taken from areas already damaged by loss in most cases, to avoid causing further damage to intact fabric. M-100 retains a very high level

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<sup>46</sup> See Appendix B for sample locations.





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of integrity, despite some areas of severe loss, and efforts were made to respect this in the sampling technique. The two floor samples were the exception to this—both were taken from intact floor fabric, to gain a full stratigraphic sample.

Samples were taken with a scalpel from the edges of areas of loss. Each sample was individually wrapped in cotton and placed in sealed containers. These were then transported back to the Architectural Conservation Laboratory at the University of Pennsylvania. There they were examined with a Nikon SMZ-U<sup>®</sup> stereoscope microscope in reflected light to determine the best areas to produce a thin section. The most intact, representative areas of these samples were chosen for thin section.

The samples were thin sectioned by Spectrum Petrographics, Inc., of Winston, Oregon. They were first embedded in sand to be shipped. The entire sample and sand were consolidated in epoxy and the sample was cut and polished. The thin sections were stained with blue dye to increase the definition and visibility of pores and voids within the samples. The shipping preparation of the first samples was poor, which resulted in several broken, but still legible, samples. In some cases, the sample was broken prior to shipping. In several of these cases, the pieces rotated during shipping, resulting in a sample whose order became finish>break>substrate>finish. Several of these samples were reconstructed using Photoshop<sup>®</sup>, in order to better understand the layer sequence.



The second set of samples was taken in the same manner, with the exception of the floor samples, which were taken with a Dremmel<sup>®</sup> tool. These samples were packed more carefully, and also sent to Spectrum Petrographics to be thin sectioned.

## 3.2 Thin Section Analysis

### 3.2.1 Methodology

The thin sections were analyzed using light microscopy. Each layer of each sample was examined and described for a number of different attributes, including layer thickness, surface texture, coarse fine ratio, layer color, matrix color, coarse fraction color, coarse fraction shape, coarse fraction sorting and boundary sharpness.<sup>47</sup> These attributes were deemed critical in characterizing and differentiating each layer.

The thickness of each layer was determined using photomicrographs. Photomicrographs were taken using a Nikon Optiphot2-Pol<sup>®</sup> microscope at a magnification of 5x and 10x, and an optical micrometer was also photographed at the same magnification. The layers were then measured using the magnified images.

Surface texture was determined in pseudo-darkfield illumination with a Nikon Microscope with an Episcopic Fluorescent Attachment EF-D<sup>®</sup>. The surface of each layer was examined in reflected light at a magnification of 5x and described using FitzPatrick's chart of surface textures.<sup>48</sup> The surface of the

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<sup>47</sup> See Appendix D for Thin Section Description charts.

<sup>48</sup> E.A. FitzPatrick, *Soil Microscopy and Micromorphology* (New York: John Wiley & Sons, 1993)



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layer was compared to the chart, and a reasonable match was determined.<sup>49</sup>

Layer color, matrix color and coarse fraction color were determined using the Munsell Soil Color Chart<sup>®</sup>, using the same methods that determined surface texture. Boundary was determined by examining how defined a soot layer preceding a layer of plaster or wash was.

Course to fine ratio was determined in transmitted light at a magnification of 10x. Again utilizing FitzPatrick, the coarse to fine ratio, coarse fraction shape and coarse fraction sorting all were visually determined using FitzPatrick's definitions of distribution.

Each of these characteristics defines each layers microstructure. Layer thickness is controlled by grain size and coarse to fine ratio and application method. For example, thicker materials are generally more graded and well sorted. Surface texture is a result of application and drying method. This characteristic is indicative of how the finish was applied, as well as how the next finish was applied on top of it. Was the finish applied, left to dry and exposed long enough to develop a layer of soot, and a new finish applied on top of that? Or was a finish applied, and another layer applied immediately on top of it, leaving a smooth finish and no soot layer between them? Another possibility could be that the soot layers present were applied as washes between layers, and considered a finish. Coarse/fine ratio in a layer indicates type and uniformity or non-uniformity between layers. Layer color is telling of the source of the



materials used to make the finish, and also of the relationship between color and element or placement on the wall. The matrix color is a result of the sources of the binder material and the course/fine ratio. Particle shape is related both to source of the material, as well as to course/fine ratio. Coarse fraction sorting is related to application method, as is the type of boundary between layers.

### *3.2.2 Analysis*

#### ***Sample BAND M-100.01—Ceiling***

Sample 100.01 was taken from the ceiling, 1.85 m from the smoke hole and 0.56 m from the west wall. There is no finish present on this sample, however it is heavily deposited with soot. The soot is 85  $\mu\text{m}$  thick, and represents a true accumulation of soot—presumably over time—during the use of the cavate. The tuff substrate attached to the sample is 2.7 mm thick. There is a sharp boundary between the soot and the substrate. There is also debris, consisting of small particles of rock, caught in the soot, probably the result of Aeolian deposition. The lack of any finish on this sample indicates that the occupants of M-100 were not using earthen plasters or washes on the ceiling. This is confirmed through visual inspection in the field.

#### ***Sample BAND M-100.02—Upper East Wall***

Sample 100.02 was taken from the upper register of the east wall of M-100, 1.60 m from the floor and 0.29 m from the north wall. It is located very close to two large features: two holes in the upper part of the wall, with a corresponding pair on the wall opposite. It is speculated that these sets of holes once





supported two beams running the width of the cavate, possibly used as a weaving loom or for storage. Unlike most of the other samples taken from the upper register, sample 100.02 has multiple layers of earthen finishes and soot. There are 20 layers all together, 10 layers of earthen finish and 10 layers of soot. The boundaries between these eight layers of soot and finish are all sharp. All of the soot layers are very thin, with only three over 3  $\mu\text{m}$ , and the remainder 1  $\mu\text{m}$  thick. The earthen finish layers are also fairly thin, with the exception of the earliest two layers. The earliest two layers are 1.35 mm and 1.43 mm thick, and have the same coarse fraction sorting (40% : 60%), colors (very dark gray), coarse fraction shape (spherical subangular, tabular) and sorting (clustered).<sup>50</sup> There is a 1  $\mu\text{m}$  thick layer of soot between them, indicating that there was probably not a long period of time between each application. However, the second layer (1.43 mm) has a wavy/very rough surface texture, unlike the first layer, which has a moderately rough surface texture. This potentially indicates that a longer period of time elapsed between the second layer of finish and the third, resulting in more wear on the wall, and that the second layer was applied shortly after the first. The third and fourth layers of earthen finish are both approximately 25  $\mu\text{m}$  in thickness, and the coarse fine ratio of both is 25% : 75%, with a slightly rough surface texture. These two layers are both very dark gray and have the same coarse fraction shape as the preceding two layers. The soot layers between the second, third and fourth layers vary in thickness from 3  $\mu\text{m}$ , to

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<sup>50</sup> During the stratigraphic analysis in this chapter, the first layer of finish described is always the earliest, and the analysis follows through to the most recent. However, the charts in Appendix D read from the most recent layer down to the earliest.



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1  $\mu\text{m}$  and 5  $\mu\text{m}$ , possibly indicating differing amounts of time between applications, varying levels of use of the space, or an increase in burning.

There is a break between the fourth layer of soot and the next layer of finish. It is interesting to note that the colors of the finish layers are different above and below this break. It is also at this point that coarse fine ratio, coarse fraction shape and sorting also change. The colors above this point are all dark brown, and the matrix colors are dark gray.<sup>51</sup> Layer thickness in these six layers ranges from 7  $\mu\text{m}$  to 70  $\mu\text{m}$ . Five of the soot layers are 1  $\mu\text{m}$ , and one is 3  $\mu\text{m}$  thick. The coarse fine ratio of the fifth layer of finish, the first layer above the break, is 50% : 50%, and the coarse fraction shape is spherical subrounded with even sorting, and has a slightly rough surface texture. It is followed by a 3  $\mu\text{m}$  layer of soot, and a 35  $\mu\text{m}$  layer of finish with a wavy surface texture, 30% : 70% coarse fine ratio, the same colors and coarse fraction shape as the preceding layer, and uniform sorting with a fuzzy boundary. The four layers of soot and finish above the sixth layer also have fuzzy boundaries, and are fairly uniform in thickness (30  $\mu\text{m}$  and 25  $\mu\text{m}$ ). The seventh layer of finish has a slightly different Munsell<sup>®</sup> color, but the matrix and coarse fraction colors are the same as the two preceding layers and three following layers.

Each of the layers above the break has a different surface texture and coarse fine ratio, but the coarse fraction shape seems to fall in pairs. All of the soot layers are 1  $\mu\text{m}$  thick. The fifth layer has a slightly rough surface texture,

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<sup>51</sup> All colors based on Munsell Soil Color Chart<sup>®</sup>.



while the sixth layer has a wavy texture. The coarse fraction shape is spherical subrounded in both. However, the coarse fine ratios are 50% : 50% and 30% : 70%, which is a rather wide discrepancy. The seventh layer has a slightly rough surface texture and the eighth a wavy texture; the coarse fine ratios are 40% : 60% and 50% : 50%, which is much closer than the preceding pair. The final two layers of finish have moderately rough and slightly rough surface textures; both have a 30% : 70% coarse fine ratio; tabular subangular coarse fraction shapes; and even sorting.

The finishes could have been applied in pairs for a myriad of reasons. One possibility is that the assumed wooden beams created a certain amount of stress on the finish surrounding them, and to stabilize and repair the area, a base “repair” layer was applied first, allowed to dry, thereby accumulating a soot layer, and another “finish” coat was applied on top. The applications would have been close enough to use the same source for materials, explaining the consistency in colors, coarse fraction shape and sorting and boundary, as well as the pattern of surface texture (rougher followed by smoother).

### ***Samples BAND M-100.03 and BAND M-100.04—Lower East Wall***

Sample 100.03 and 100.04 consist of 24 layers, 12 of soot and 12 of earthen finish. The sample delaminated during sampling, was initially considered two samples. For the purposes of analysis, it is considered one. This sample was taken from the north half of the east wall, 0.87 m from the floor and 0.75 m from the north wall. When the sample was taken, it delaminated into two pieces.



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Sample 100.03 is the top, consisting of 20 layers, and sample 100.04 is the bottom, consisting of four layers.

What is striking about this sample is the consistency of coarse fraction shape throughout. All of the layers are spherical rounded, spherical subrounded or subspherical subrounded, and only two layers contain a substantial amount of tabular subangular particles. The coarse fraction sorting is also consistent throughout, defined as uniform for the most part, or even in several layers, as is the color, which ranges from yellowish brown in the first three layers to a series of dark browns and grays.

The first three layers of finish, present on sample 100.04, are all the same color, light yellowish brown, have the same coarse fine ratio, coarse fraction shape and sorting. The first layer, like other samples, is a very thick layer, 2.9 mm. It was probably used as an initial layer to level the tuff wall behind it. The following two layers are much thinner, both 10  $\mu\text{m}$ . These three layers almost certainly came from the same source. The surface texture of the first layer is wavy, possibly due to it being the first application on a rough surface. There is a sharp soot boundary between this layer and the next. The surface texture of the second layer is slightly rough, indicating, from its position in the lower half of the wall, that it did not receive much abrasion before it was refinished.

The layers of the sample that make up sample 100.03 are generally much darker than the first three. The surface texture on all of these layers is quite rough. Based on the location of the sample in the lower part of the wall, this would have been an area of steady use. The area is heavily embellished, and





below the most recent dado. The occupants of the cavate would have come into contact with this area frequently, which would result in a rougher texture of the surface than in higher locations.

***Sample BAND M-100.05—Lower East Wall***

Sample 100.05 was taken from the lower wall east wall on the north half, 0.32 m from the floor and 0.63 m from the north wall, almost directly below samples 100.03 and 100.04. The sample consists of 28 layers, 14 layers of soot and 14 layers of earthen finishes. Most of the layers are fairly thin, the thickest being the first two at 1.56 mm and 2.35 mm, separated by a 5  $\mu$ m layer of soot between them. This thick layer of soot suggests a long period of time elapsed between finishing, or that there was heavy soot deposition as a result of the proximity of the hearth. These first two layers are both light brownish gray, and have the same characteristics. The coarse fraction sorting is 40% : 60%; the matrix color is gray; coarse fraction shape is spherical angular with even sorting, and the boundaries are sharp. The texture of the first coat is wavy, probably due to the uneven surface of the tuff being plastered. There is a thick layer (5  $\mu$ m) of soot between the two layers. The surface texture of the second layer is moderately rough. These first two layers are probably initial coats to level out and smooth the wall surface. The coats of finish above the initial two range from 5  $\mu$ m to 45 $\mu$ m, all fairly thin. Six of these ten upper layers have a coarse fine ratio of 40% : 60%, and six of the ten have a moderately rough surface texture. Two of the layers have a coarse/fine ratio of 20% : 80%, and both of these have



a wavy surface texture. They are both grayish brown, and have similar coarse fraction sorting. They are also both very thinly applied layers, only 5  $\mu\text{m}$  and 18  $\mu\text{m}$  thick. The coarse fraction shape of all of the layers is some variation of spherical, with the majority being spherical subrounded (6).

There is no discernable pattern in any of the characteristics, except for the matrix color. For the first seven layers, the matrix is gray, and the resulting colors are darker. For the last seven layers, the matrix is light brownish gray, and the resulting colors are lighter.

It is possible in this area that the occupants were applying a floor band, which might explain the color choices in this area of the cavate. All of the layers are light grays and browns. Assuming that this lower register was being more heavily used than the upper registers of the walls, occupants would have been leaning and rubbing on these areas of finish. While initial applications may have been thicker, the use of this space would have resulted in heavy wear. This would explain the very thin layers that are seen today.

### ***Sample BAND M-100.06—Lower West Wall***

Sample 100.06 was taken below the most recent dado line on the north half of the west wall, 0.78 m from the floor and 0.41 m for the north wall. Here again the sample begins with two very thick layers, the first 2.30 mm thick and the second 2.95 mm thick. There is a slightly thicker layer of soot, 2  $\mu\text{m}$ , between them, and another 3  $\mu\text{m}$  thick layer following. Both of these layers are very dark gray, and have fairly even coarse/fine ratios, 40% : 60% and 50% :



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50%. The coarse fractions shape in both layers is spherical subrounded with uniform distribution. The thickness and similarities of these two layers again indicates the possibility that the occupants were intentionally applying a thick initial coat to level and smooth the surface of the wall.

The layers following these two are also very dark in color, and vary in thickness. The surface texture ranges from moderately rough to very rough, indicating an area of heavy use. This sample was taken just above the grinding area of the cavate, an activity that would have subjected it to an intense amount of human contact. It is curious that there are not more layers in this sample, considering its location in such a high usage area. It is possible that layers wore off entirely before the area was refinished, decreasing the number of layers present in the sample.

***Sample BAND M-100.07—Middle West Wall***

Sample 100.07 was taken directly above sample 100.06, on the north half of the west wall, within the area of the Dado B. It consists of 23 layers, 12 layers of soot and 11 layers of finish. The thickness of the layers ranges from 15  $\mu\text{m}$  to 1.05 mm, and all of the colors are dark gray or grayish brown. The coarse fraction of all of the layers is well sorted, particularly in the top two layers.

Judging from the colors, coarse fraction shape and sorting, the same source was used for all of these layers of finish. All of the colors—layer, matrix and coarse fraction—are very similar, and produced a visually consistent finish over time, with only moderate variation in texture. The layer textures vary from



slightly rough to very rough, with the majority being moderately rough. This consistency in texture is most likely a result of the location and application methods. It is above an intensively used area, but high enough that it did not receive the wear that the area around 100.06 would have.

It is interesting to note that there are more layers in sample 100.07 than in 100.06, even though sample 100.06 is in the lower one-third of the wall and would be expected to have more applications than anything above it. However, 100.06 was in a heavy use area, and any additional layers might have been worn away, while 100.07 probably did not receive the same amount of contact.

The color scheme begun in 100.07, of very dark grays, continues through into the presumably later layers of 100.06. This indicates that although the height of the dado changed the occupants were continuing used the same colored finishes as they had in the past.

### ***Sample BAND M-100.08—Lower West Wall***

Sample 100.08 is an anomaly. Taken 0.86m from the floor and 1.32 m from the north wall, it is between samples 100.06 and 100.07, on the west wall. However, rather than have a similar layer structure to either of those samples, it is very different. There are only two layers of finish and two layers of soot in this sample, as compared to the 14 layers in sample 100.06 and 23 in 100.07. The first layer of sample 100.08 is one of the thickest layers present in any of the wall samples, 3.5 mm. It is followed by a 1  $\mu$ m layer of soot, a 56  $\mu$ m layer of finish and a 2  $\mu$ m layer of soot. Both of the finish layers are dark gray, with a 40% : 60% coarse fine ratio; spherical subrounded and tabular angular coarse fraction





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shape and even sorting. The materials are obviously from the same source, and possibly applied one right after the other. There is a sharp boundary of soot between the two layers.

It is unknown why this sample has dramatically fewer layers than the other samples taken from this height on the wall. Because it was an anomaly, samples 100.14 and 100.19 were taken for confirmation, and showed unexpected results. Sample 100.19 was taken just below 100.08 (0.3 m from floor, 1.46 m from door) and has 40 layers of soot and finish, while 100.14 has 3 layers, but is much darker in color than 100.08. 100.08 was taken from the edge of the large area of loss next to the entrance of the cavate, and it is possible that the original layers of finish, like those in 100.19, were lost during the period between abandonment and the possible reuse during the Pueblo Revolt period, and were refinished during the Revolt occupation (assuming that there was reoccupation at this time). It is also possible that this area of the cavate was treated differently than the areas further inside.

***Sample BAND M-100.09—Niche Floor***

Sample BAND 100.09 was taken from the floor of the niche in the north wall, 0.80 m from the floor and 0.86 m from the west wall. This sample was taken to investigate whether or not the occupants of M-100 treated architectural features the same as the walls, or if they were treated individually. Sample 100.09 points to the conclusion that architectural features, such as wall niches, were treated differently than the walls.



Like the rest of the cavate, this sample begins with a thick layer of finish 8.3 mm, and is followed by nine layers of alternating soot (5) and finish (4), for a total of ten layers. The coarse fraction of all of the layers is extremely well sorted, four of them 50% : 50% and one 60% : 40%. All of the layers are gray, and get lighter in color as they decrease in age. The coarse fraction shape of each of the layers is similar; two are subspherical subrounded and three are spherical subrounded. It is likely that the occupants used a different source of material for the subspherical subrounded finishes. These two layers have other similar characteristics as well: both are very dark gray, and the coarse fine ratio for both is 50% : 50%. These two layers follow the initial layer, which is also dark gray. The top two layers are also similar in their characteristics: both have a slightly rough surface texture; both are dark gray with spherical subrounded coarse fraction particles and even sorting. The boundaries between these three layers (two finish, one soot) are fuzzy.

***Sample BAND M-100.10—Niche Wall***

Sample BAND 100.10 was taken from the top left (west) wall of the niche in the north wall, 0.90 m from the floor and 0.56 m from the west wall. This sample was taken for the purposes of comparison with Sample 100.09, to confirm whether or not the niche was treated differently than the walls. There are 12 layers of finish on the walls of the niche, six finish and six soot. The initial layer is identical in characteristics to the first layer in sample 100.09. This layer in sample 100.09 is slightly thicker than 100.10 (8.3 mm vs. 5.6 mm), however it



is likely that the floor of the niche and the walls were treated differently, explaining the difference in thickness. The coarse fraction in all of the layers is between 50% and 60%, relatively high, and the coarse fraction shapes are spherical angular, subspherical angular, spherical subrounded and tabular angular. The colors are dark reddish brown, excluding the first layer, which is light yellowish brown, and the same color as the floor of the niche.

***Sample BAND M-100.11—Upper South Wall***

Sample 100.11 was taken from the bottom of the west smoke hole on the south wall, 1.40 m from the floor and 0.37 m from the west wall. It consists of two layers of very thick dark gray plaster. Both layers are over 2 mm in thickness (2.5 mm and 2.6 mm), and have a wavy surface texture. The coarse fraction sorting and coarse fine ratio is identical, as is the shape in both layers. There are several large inclusions in each layer, of milky white particles. There is one large particle in the first layer that is surrounded by a red aura.

***Sample BAND M-100.12—South Wall, East Smoke Hole***

Sample 100.12 was taken from the upper east side of the east smoke hole, on the south wall, 1.73 m from the floor and 0.63 m from the west wall. It consists of a 6.3 mm thick layer of soot on tuff. Like sample 100.01, there is rock debris caught in the soot. Both of these samples demonstrate that the smoke holes were not being fully finished and that the ceiling areas display thick accumulations of soot.



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***Sample BAND M-100.14—Upper West Wall***

Sample 100.14 was taken from the south half of the west wall, 1.58 m from the floor and 0.40 m from the door. This sample consists of two very thick layers of plaster, and a layer of soot on top. The first layer is 1.90 mm thick, and the most recent layer is 1.73 mm thick. Both layers are very dark gray, and have a pinkish gray coarse fraction color, as well as light gray. The matrix color of the most recent layer is black, however, one of the darkest layers in any of the samples.

***Sample BAND M-100.15—Floor***

Sample 100.15 is a floor sample, taken at the juncture of the wall and floor on the north wall, 0.17 m from the east wall. The purpose of taking this sample was to examine whether or not the occupants of M-100 were lapping the floor finishes up onto the walls to create a floor band around the space. They do not appear to have employed this method. The floor, however, is interesting on its own. There are 17 layers on the floor, 10 finishes and seven dirt or soot. Like the rest of the cave, the floor began with a very thick layer of plaster, 1.15 mm thick. The following layers are similar in thickness to the washes on the walls, and the amount of dirt and soot between these layers is consistent with that on the walls as well. The coarse/fine ratio of the majority of the layers (6) is 40% : 60%, and the rest are 50% : 50%. The coarse fraction shape is more varied in the first four layers, ranging from tabular to spherical subrounded. The fifth through tenth layers are consistently spherical subrounded, which may indicate regularity in a source of materials for the floor finishes. The coarse fraction





colors are also the same in these layers, which is also indicative of regularity of source. Two layers, in addition to the white coarse fraction of the other layers, have a light reddish gray component, giving them their pink appearance. The top three layers of the floor are black. These three layers retain the same coarse fraction sorting, color and shape as the previous layers, but the matrix is black. This is an interesting change from the previous colors, which are much lighter. This change could indicate a change in use, or a later occupation.

***Sample BAND M-100.19—Lower West Wall***

Sample 100.19 was taken from the south half of the lower west wall, 0.3 m from the floor and 1.46 m from the door. This sample has 40 layers, the most of any of the samples. Like the other samples, 100.19 has a layer of soot between each layer of plaster or wash, beginning after the first layer of plaster was applied. All of the layers are well sorted, ranging from 40% : 60% to 50% : 50%. The majority of the coarse fraction shape is spherical subrounded, with some tabular subangular, spherical subrounded and spherical subangular particles as well. The coarse fraction sorting ranges between uniform and even. This sample begins again with a thick layer (2.88 mm) of light brown plaster, similar to the other samples from the cavate. The colors of the washes range from light brown to reddish brown and gray to dark grayish brown, and are some of the most vibrant in the cavate.



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### 3.3 pH and Conductance

#### ***Methodology***

Two samples were chosen for salt, pH and conductance tests. Sample 18, a sample of tuff, was taken specifically for this purpose. Sample 4, a finish sample, was chosen for three reasons: it is the first layer of finish applied to the cavate wall, so the assumption was made that if salts were leaching through the rock, they would be visible in this layer; it is from the back of the cavate, while 18 is from the front; also, 4 was the only sample large enough to have the required amount of material for analysis(1g).

#### ***Salts***

The analysis for salts was carried out using a standard wet-chemical procedure. A portion of Samples 4 (plaster) and 18 (tuff), weighing approximately one gram each, were ground to a fine powder using a mortar and pestle. These powders were then placed in beakers, and 100 ml of deionized water was added to each to form a solution. They were agitated gently by swirling the beakers. The pH and conductance of each solution was then tested, described below. The solutions were then filtered, each through #2 filter paper in a funnel to another beaker. The resulting solutions were then dried in a 90° C oven until the water evaporated. When the beakers cooled, 20 ml of deionized water was added to each to dissolve the remaining salts. Approximately 2 ml of each solution was drawn off to 8 test tubes, with 4 test tubes of deionized water prepared as controls.



In order to test for the presence of sulfates, 2 drops of 2N hydrochloric Acid (HCl) was added to one test tube containing the plaster solution, one containing the tuff solution, and one containing deionized water. 2 drops of Barium Chloride ( $\text{BaCl}_2$ ) were then added to each of the three test tubes. To test for chlorides, 2 drops of 2N nitric acid ( $\text{HNO}_3$ ) and 2 drops of 0.1N solution of silver nitrate ( $\text{AgNO}_3$ ) were added to two more test tubes, and a control. To test for nitrites, 2 drops of 2N acetic acid ( $\text{CH}_3\text{COOH}$ ) followed by 2 drops of Greiss-Ilosvay's reagent were added to two additional test tubes, and a control. To test for the presence of nitrates, a small amount of zinc powder was added to the same test tubes and the control used for test #3. Finally, to test for carbonates, 2 drops of HCl were added to the two more test tubes and a control. These final test tubes contained the solids previously filtered out of each solution.

The tests yielded negative results for sulfates, nitrites, nitrates and carbonates in the tuff. Positive results were obtained for chlorides. The tests in the plaster yielded negative results for chlorides, nitrites, nitrates and carbonates. Positive results were obtained for sulfates, although not in abundant quantities.

### ***pH and Conductance***

The conductance of the soluble salts separated from the earthen material of Sample 4 and the tuff of Sample 18 were measured using commercial pH strips and an Omega<sup>®</sup> pH/Conductivity Pocket Pal Meter. The solutions used for measurement were the solutions of powdered sample and deionized water



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described above. The conductance meter was rinsed with deionized water, and then calibrated using standard solutions, indicating that the meter was properly calibrated. The conductance meter was then immersed in each solution three times to confirm the reading.

The pH of both the earthen material and the tuff was measured with the meter described above, and with pH strips. The pH meter was calibrated using standard prepared solutions.

After the solution was agitated and before it was filtered and dried, the meter was used to measure the pH and conductance of the solution. The meter electrodes were immersed in the solution until a reading stabilized on the display. The pH was also tested with the commercial indicator strips. These strips are impregnated with standard indicator chemicals, and display colors that reliant on the pH of the solution tested. The strips were immersed in each solution and visually compared to color standards on the strip container.

The conductance readings for both solutions were extremely low. The conductance of the earthen material was 250 $\mu$ m, indicating an insignificant amount of electrolytes. The conductance of the tuff was even lower, at 30 $\mu$ m, also indicating an almost absence of electrolytes.

The pH reading for both materials using the commercial strips was 6. The pH of the deionized water was also 6. The pH of the earthen material using the Pocket Pal was 6.80, and the pH of the tuff using the meter was 6.30. The neutral pH of both materials indicates a relatively stable environment.





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### 3.4 Conclusions

The samples taken throughout the cavate are composed of generally similar materials. The matrix particles consist of fine clay and silt fractions, particles too small to be resolved without special equipment. The matrix particles generally consist of various shades of brown, including some light enough to be considered yellow, to reddish brown through to very dark shades; grays; black; and a few pinks. The matrix imparts its color to the layer as a whole, to achieve the overall color.

The aggregate, or coarse fraction, is mainly quartz, with some tuff. There are two different types of tuff available in Frijoles Canyon, Otowi and Tshirege Tuffs. Otowi Tuff is pale red in color, while Tshirege Tuff is yellow or buff in color. Both are lightweight and friable, and make up much of the sand available in the area. The Architectural Conservation Laboratory conducted petrographic analysis of both of these tuffs in 1998:

“The red Otowi is a crystal-tuff. Quartz and sanidine feldspars are evident in a matrix of glass shards and dust. Weathered ferromagnesian minerals are dispersed throughout the matrix. Vacuoles contain an-isotropic pumice fragments. The quartz and feldspars show sign of embayment.

“The yellow Tshirege tuff is also a crystal-tuff and very similar to the red Otowi Tuff. Quartz and sanidine feldspars are evident in a matrix of glass shards and dust. Vacuoles contain an-isotropic pumice fragments. The quartz and feldspars show signs of embayment.”<sup>52</sup>

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<sup>52</sup> *Trail Preservation Study, Tsankawi Mesa, Bandelier National Monument, Los Alamos County, New Mexico, National Park Service, USDI.* Prepared by The Architectural Conservation Laboratory, Graduate Program in Historic Preservation, University of Pennsylvania. May 1998, p.120.



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As a result of its friability, tuff deteriorates easily and rapidly, making it the most abundant source of aggregate in the area.

The distribution of the finish thickness indicates that the median thickness is between 10  $\mu\text{m}$  and 40  $\mu\text{m}$ . These layers, up to 80  $\mu\text{m}$ , would constitute a wash. The layers range in thickness from 4  $\mu\text{m}$  to 8.33 mm. Any layer thicker than 8.0 $\mu\text{m}$  should be considered a plaster. Comparing this result with the definitions employed by Mesa Verde and the C.A.S.P.A.R project, they are fairly consistent. C.A.S.P.A.R.'s definition of defining any finish up to 1 mm as a wash, and anything thicker than 1 mm as a plaster, could be employed at Bandelier, however further investigation in other cavates is necessary before that determination is made.<sup>53</sup>

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<sup>53</sup> See Appendix D for graphs of layer thickness.



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## Chapter Four Conclusions

### 4.1 Interior Finishes

The stratigraphic analysis of the previous chapter shed light on many of the techniques used by the occupants of M-100 in their application of earthen architectural finishes to the walls and floor of the cavate, as well as their treatment of the cavate as a whole. This chapter aims to elaborate on the patterns seen in the stratigraphic analysis, and produce examples of potential finish schemes that could have existed in M-100.

A question that has beset this investigation from the beginning is the idea of how internal space was defined and created in ancestral Puebloan architecture.<sup>54</sup> Watson Smith defines a wall as a vertical surface that is usually planar, but sometimes curved. Because cavates are largely constructed through the subtractive process of excavation, the internal space created is not bound by the limitations of additive construction methods (e.g. stone masonry with wooden roof beams).<sup>55</sup> Cavate interiors show great variability in size, plan and ceiling configuration.<sup>56</sup> In those cavates identified as habitation spaces, most, if not all, possess numerous applications of earthen finishes on the ceilings, which are instead heavily sooted. This suggests certain normative treatments for the different surfaces or elements that define a cavate living space. Considering the curved and continuous nature of the walls of the cavates in Frijoles Canyon, this

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<sup>54</sup> Frank G. Matero, personal communication with author, April 20, 2000.

<sup>55</sup> Watson Smith, *Kiva Mural Decorations at Awatovi and Kawaika-a*, Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol.37 (Cambridge: Peabody Museum, 1952), p.13.

<sup>56</sup> H. Wolcott Toll, *An Analysis of the Variability and Condition of Cavate Structures in Bandelier National Monument* (United States Department of the Interior, 1995) p.78.



definition is inadequate. Instead the application of finishes to the vertical and curved vertical planes may define what is wall according to emic definitions related to the living zone, i.e. the vertical space inhabited during sitting.<sup>57</sup>

Judging from the pattern of finish in the stratigraphic analysis, coats of wash were renewed at certain intervals of time. Watson Smith observed this same phenomena during his investigation at Awatovi. There is no way to know exactly when this renewal took place, either at Awatovi or in the cavates, however Smith speculates that it took place at least once a year, if not more frequently. Smith derives his conclusion from the number of layers of finish present and the practice that he observed in Pueblo villages during his investigations.<sup>58</sup>

Smith presents four possible explanations for the renewal of the finish coats: partial disintegration or collapse of the finish; for the purpose of eradicating the layer of soot accumulated on the surface; customary renewal, similar to a spring cleaning; and ceremonial purposes, for the purpose of destroying or hiding the sacred object after it has served its religious purpose.<sup>59</sup>

The first scenario, of partial collapse or disintegration, is a likely one in some areas of M-100. General collapse is an unlikely problem in continually occupied cavates because of regular maintenance, however the area of and around the grinding area would have received an intense amount of regular use.

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<sup>57</sup> Frank G. Matero, personal communication with author, April 20, 2000.

<sup>58</sup> Watson Smith, *Kiva Mural Decorations at Awatovi and Kawaika-a*, Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol.37 (Cambridge: Peabody Museum, 1952), p.19.

<sup>59</sup> *Ibid*, p.19.





This continuous activity would have worn the finish down, and necessitated the refinishing of the area, probably more frequently than the rest of the cavate. The intensity of the use in this area would also explain the lack of layers present in sample BAND 100.06, which was taken from this area. The continual wear on this area would have promoted the loss of successive layers of finish, wearing some of them completely away, rendering them undetectable today.

The second scenario, the eradication of the soot that accumulated on the surface of the finish, is unlikely as a sole reason for refinishing. Also, the presence of soot between every layer indicates that the layers of finish were applied over the sooted surfaces of previous finishes and that the finishes were single layer campaigns. There is an enormous continuity in this process, as it continues throughout the occupation of the cavate. As seen today, the embellishments in this cavate and in others are intentionally incised into the black layer on top of the plaster. This technique creates a startling contrast between the black surface and the tan dado allowed to show through. This method is visible in previous layers as well, in areas where more recent layers have delaminated. There is also evidence, as noted in the previous chapter, that this black soot layer was manipulated with water, rather than simply soot deposited.

The amount of soot present between the layers is also a telling characteristic of the time elapsed between applications, and could lend credibility to the third scenario, a customary renewal of the finish. The majority of the soot layers measure  $1\mu\text{m}$ , signifying that a regular amount of time was elapsing between applications. The variations in the amount of soot deposition could be a



result of a number of factors: there was a lapse in occupation; that particular winters were colder than others, and therefore more burning took place inside the cavate. The consistency of this measurement is overwhelming, however, and is a persuasive argument for a ritual renewal process.

The fourth scenario presented by Smith is the ceremonial annihilation of sacred images after they have served their religious purposes. The focus of Smith's study was the kivas of Awatovi and Kawaika-a, and this ceremonial process has been observed in modern Pueblos.

In light of the above discussion, there are two possibilities for the refinishing of M-100: disintegration and reapplication of the finishes in some areas of the cavate, and customary renewal of the finishes over the entire cavate, particularly in the dado area. It is possible that the inhabitants of Frijoles Canyon were practicing ritual refinishing, in their living spaces. This refinishing could have been tied to spring ceremonies, and would be both functional and ritual. The consistency of the thickness of the layers of soot between the layers of finish is overwhelming, indicating a set amount of time between applications. Adolf Bandelier also reported this tradition of ritual renewal at Jemez Pueblo, much closer to Frijoles.<sup>60</sup>

What the interior of M-100 looked like over time is a difficult question to answer. The stratigraphic analysis was an enormously enlightening exercise, but still may not provide the information necessary to determine individual finish schemes. There are descriptions of the cavates and their finishes from Frijoles

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<sup>60</sup> Ibid, p.20.



Canyon, the earliest published from James Stevenson in 1882: "the lower part of the walls was sometimes plastered in one color, the upper part in another, a broad dark brown stripe being the line of demarcation."<sup>61</sup> Hewett also noted the finish patterns, saying "in some of the rooms dado are executed in tasteful patterns of yellow and two shades of red."<sup>62</sup>

Stevenson's comment is interesting, in light of the results of the analysis of sample BAND 100.07. Located in the second dado (Dado B), the layers of BAND 100.07 are very different than sample BAND 100.06, located directly below it. There are 11 layers of finish present in 100.07, and only 7 layers in 100.06, located in the most recent dado (Dado A). All of the colors of 100.07 are very dark, and do not appear to match the layer applications of the lower dado. Anamolous layers suggest that this area could have been a band, such as the one described by Stevenson.

The scenario above is a likely one. Given that no samples were taken from Dado C, we cannot be sure exactly what form the finishes took in this area. We can, however, speculate based on what is certain. With the evidence gathered, a fairly concrete picture arises: the occupants of M-100 applied two coats of leveling plaster, each over 1 mm thick; the field extended from the dado to the beginning of the curved ceiling, and was only applied twice in a very dark brown or gray finish; a dado was applied and reapplied frequently over the life of

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<sup>61</sup> James Stevenson, 1882, in Watson Smith, *Kiva Mural Decorations at Awatovi and Kawaika-a*, Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol.37(Cambridge: Peabody Museum, 1952), p.68.

<sup>62</sup> Edgar L. Hewett, revised by Bertha P. Dutton, *The Pajarito Plateau and its Ancient People*, 2<sup>nd</sup> ed. (University Of New Mexico Press, 1953) p.53.



the cavate, occasionally changing height; and the field and dado overlapped in the middle, resulting in the odd configuration of BAND 100.07.

### *Dados*

The lower layers, usually the first two applications, are the thickest in all of the dado samples. They are much thicker than an acceptable variation in the application method, leading to the assumption that these layers were used as leveling or smoothing plasters. Leveling plasters are the first coats applied, to level out the rough tuff surface throughout the cavate. A layer of soot present between these two coats suggests that the first two layers of plaster were also treated as a finish. The soot, which measures 1 $\mu$ m, indicates that the same amount of time was allowed to pass between these coats as it was with the later washes. Another possibility is that the preparatory layer was applied, the cavate ceiling sooted to seal or cure it, and the second layer of plaster applied.

### *Fields*

There are far fewer layers on the upper walls, the maximum being 10 plasters and washes in Sample BAND 100.02, Samples BAND 100.11 and BAND 100.14 having only two layers each. The occupants were clearly applying partial finishes (dados) to the walls, leaving the same layer of finish on the upper walls, with exposed multiple reapplications to the dados.

The walls were finished to their full height, and finish terminates at the juncture of the ceiling and the wall. This leads to the conclusion that the occupants of M-100 considered this area part of the wall, separate from the ceiling.





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### *Niche*

Samples BAND 100.09 and 100.10 provide some interesting information about the treatment of niches by the occupants of M-100. There is a clear differentiation between the treatment of the floor (BAND 100.09) and the walls (BAND 100.10) of the niche. The floor is finished in light browns and grays, while the walls are dark reddish browns. The walls of the niche were finished the same colors as the dado applied to the walls. It is likely that the dado formed an aura around the niche, however no samples were taken from this area. The walls were finished six times, and the floor five times. The most recent layer of the floor is a very thick layer of plaster, rather than a wash. This is the only sample in which the most recent layer is a plaster. There is also soot present between the layers of finish in the niche, indicating that the niche was not being sealed off between applications.

### *Floor*

The floor of Cavate M-100 was treated comparable to the dados, until the most recent three layers. The floor also begins with a thick plaster preparatory coat, followed by nine layers of wash, similar in thickness to the walls. The colors of these washes are light grays, yellows and pinks. The most recent three applications, however, are integrally black. This is a sudden departure from the light colors originally used. This sudden shift in color could indicate a change in use or a later occupation.

### *Finish Schemes*

It is impossible to be sure what Cavate M-100 looked like at any one given point in its lifespan. However, comparing patterns of colors and frequency of



layers from the thin section statigraphies, it is possible to construct some potential schemes.<sup>63</sup> We know from the thin section analysis that the field of the cavate was one color throughout the life of the cavate. It is possible, as evidenced by BAND 100.02, taken from the rear corner of the east wall, that the rear of the cavate was treated differently than the front section. The dados were finished much more frequently than the upper parts of the walls. These finishes had much more variation in color, as well as height. From the visible evidence, we can see that the dado changed height over time, beginning 1.29 m from the floor (Dado C), dropping to 1.02 m (Dado B), and the most recent application 0.83 m from the floor (Dado A).

The information gathered leads to several conclusions: the finishes were applied one layer at a time, and no finish application has more than one layer; the dado is applied more frequently than the field, as seen by the thin section comparison; the walls have more than one element, a dado and a field, for most of the time. A band at the juncture of the field and the dado may have occurred.

## 4.2 Embellishments

Cavate M-100 has a large number of incised embellishments on its walls, both on the most recent layer of finish and below it on previous layers. These embellishments are for the most part incised into the layer of black wash applied over the most recent dado, but some are incised below this black area, directly

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<sup>63</sup> See Appendix E for possible schemes.



into the sooted dado. This was the predominant method of application in Frijoles Canyon that can be recorded with the eye. Kenneth Chapman, while working with Edgar Hewett, recorded many of the embellishments present in the cavates, and said there were a "large number of drawings incised into the smoke-blackened clay-plastered walls...all incised into the plaster, which was frequently renewed by the application of fresh coats."<sup>64</sup> M-100 was one of the cavates surveyed by Chapman, who, along with Carlos Vierra, was inspired to take on the survey as a result of the vandalism suffered by the cavates.

These embellishments have been continuously deteriorating over time, without the application of fresh coats of plaster. Detachment and delamination in the areas where the embellishments were applied are the major cause of their loss. There is a significant amount of delamination and detachment on the lower sections of the walls, in the dado and soot blackened areas. Was the application of these embellishments the catalyst for these conditions, or are there other causes and the loss of the embellishments a result?

Detachment followed by delamination is the cause of the loss of the embellishments on the north wall. The evidence for this lies in one embellishment, recorded intact early in the last century (see Figure C.28, Appendix C). This embellishment was just right and slightly below the niche. Glenn Haynes recorded this figure again in 1951. It was partially intact in 1951—its head, shoulders and most of its torso were gone, leaving both legs, its arm

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<sup>64</sup> Kenneth Chapman, in Watson Smith, *Kiva Mural Decorations at Awatovi and Kawaika-a*, Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol.37(Cambridge: Peabody Museum, 1952),p.69.



and a small section of its chest (Figure C.6, Appendix C). The most recent layer, which this figure was incised into, had delaminated from the layer below and fallen off; the layer underneath is still attached to the wall in this photograph. This area of the cavate was recorded again in June 2000 (Figure C.10, Appendix C). This figure is entirely gone today; the layers of finish have completely detached and delaminated. Everything in the soot and dado area is detaching, from the floor to 1.32 m above it. Delamination is creeping towards the other embellishments on the wall, threatening their loss as well. The east wall suffers from this same pattern of deterioration in the sooted and dado areas.

The most likely causes for loss on this wall are freeze/thaw cycling or poor adhesion between the soot and finish. This area of the cavate is probably not getting wet directly, but it is possible that some moisture from condensation has penetrated the layers, causing detachment. Delamination is an active condition in this area, as indicated by the earlier photographs.

A pattern of delamination is seen on the west wall, surrounding the areas of loss and extending into the dado and sooted area. This area is almost definitely getting wet, from both wind-driven rain and snow. Freeze/thaw cycling probably plays a major role in the loss of finish in this area, as well as shrinkage from the wet/dry process. Existing total loss in association with perimeter delamination suggests a chronic problem of tactile deterioration in this area. Mechanical abrasion probably plays some role in the deterioration on this wall as well, near the entrance. If the area adjacent to the entrance was embellished, these have been lost. (Figures C.1 and C.2, Appendix C) The dado on the





south wall is also experiencing delamination. This area could also be a casualty of wet/dry and freeze/thaw cycling, from rain and snow blowing east into the cavate, as a result of the intense storms in the summer that come from the west.

The embellishments incised into the sooted area and dado could be the cause of some of the deterioration seen in Cavate M-100. The method of incision could have created an entry point for water or water vapor between the most recent layers of plaster, creating an ideal environment for freeze/thaw cycling.

#### **4.3 Mechanisms of Deterioration**

Delamination and detachment are the major causes of loss and deterioration in Cavate M-100. The reasons for these conditions is not certain, however there are several likely causes.

Each layer is separated by a layer of soot or carbon, applied or deposited. In thin section, the breaks that occurred in the samples occurred horizontally at the juncture between the greasy carbon soot layers and the finish layer. Judging from this, it is probable that the layer of soot between each layer of finish prevented the creation of a strong adhesive bond at the plane of contact. The lack of a strong adhesive bond between these layers creates a situation ideal for delamination and eventual loss, depending on external factors.

Freeze/thaw cycling could be another possibility for the delamination and detachment seen in the cavate. Trapped moisture between layers of plaster or thinner washes freezing and expanding would cause damage resulting in the



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delamination of layers. Wet/dry cycling, causing the expansion and shrinkage of the clay fraction, would cause internal stress cracking and eventual collapse. It could also cause lamellar distortion of delaminated layers (cupping and blistering), which could lead to loss.

Mechanical abrasion is another possibility for the deterioration of the finishes in Cavate M-100, particularly on the west wall. Driving rain or snow entering the cavate and making contact with the finishes and tuff would cause substantial deterioration. Wind abrasion could also contribute to loss through mechanical abrasion. Wind-blown sand particles consistently abrading the surface finish would eventually wear them away, layer by layer. Without intervention, the result would be severe deterioration, which can be seen.

Disaggregation is an active condition in Cavate M-100, in the areas of total loss. Evaluating the locations of this condition, it is likely that water is being absorbed into the tuff by capillary action around the opening of the cavate. The presence of disaggregation is indicative of a cycle of loss, beginning with delamination and detachment, and resulting in total loss. The disaggregation begins again on the exposed, naturally friable tuff.

All of these mechanisms are active conditions, which must be addressed in order to preserve and protect the interior finishes and embellishments in Cavate M-100.



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## Chapter 5 Recommendations

In order to complete the picture painted of a cavate by this thesis, further investigation and testing is needed in Cavate M-100, as well as in other cavates in Bandelier National Monument. Testing similar to that done in this thesis is an excellent starting point, however the materials used to create the earthen finishes used in the cavates warrants a more in depth analysis.

Additional samples should be taken from Cavate M-100, and the same analyses done here applied to these samples. Sample locations should be chosen to supplement the samples already taken. More samples should be taken from the fields on all of the walls, in order to verify that only 2 layers were used over most of the area and if certain areas were treated differently. Samples should also be taken from Dado B and Dado C. Only one sample was taken in Dado B, and none in Dado C, for this analysis. Samples from these areas would shed light on the evolution of the finish schemes used in the cavate, giving better evidence for the earliest finishes. Samples taken from all of the dados and the field on the north wall would be beneficial in understanding the schemes used on this wall. No samples from any of these areas were taken. Samples should also be taken from all of the architectural features in the cavate, with the exception of the niche on the rear wall, which has already been sampled. It is known from the samples taken from the niche that this feature was finished in a manner to differentiate it from the rest of the space. It is possible that the other architectural features were finished in this manner as well.



General characterization of the composition of the samples should be performed as well, using techniques such as X-Ray Diffraction and Scanning Electron Microscopy (SEM) with an Energy Dispersive X-Ray Analyzer (EDS). These methods of instrumental analysis will identify the basic elemental composition of the finishes.

Further chemical characterization of the composition of the finishes should be undertaken as well. Scanning and Transmitted electron microscopy (SEM/TEM) are methods of analysis that may facilitate the analysis of individual layers of finish. TEM is a far more precise method of microscopic analysis than SEM/EDS. Its spatial resolution is a much narrower range than SEM. This precision allows individual components in a given layer to be analyzed independently using both qualitative and quantitative microanalyses, employing EDS. TEM analysis can identify the elements present in each layer, identify even the smallest particles individually and analyze minor components. It can also differentiate organics and inorganics, which can aid in sourcing original and replacement materials.<sup>65</sup>

Infrared microspectroscopy is another method of analysis that can potentially be used to characterize individual layers of earthen architectural finishes. Infrared microspectroscopy uses apertures to isolate the area of interest or individual layer in a thin cross section of a multi-layer sample. This

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<sup>65</sup> Carlos Barba, et al., "A Note on the Characterization of Paint Layers by Transmission Electron Microscopy." *Studies in Conservation* (Vol.40, Number 3, August 1995) p.194.





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method can determine the composition of each layer, identifying both organic and inorganic compounds.<sup>66</sup>

Experimental construction and finishing of a cavate would also be an interesting and viable method of investigating cavate construction, finishing and sooting techniques. Used in conjunction with possible sources of material, techniques for the composition and application of earthen finishes can be explored. These can then be analyzed in thin section and compared to the prehistoric finishes for similarities or differences.

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<sup>66</sup> Michele R. Derrick, Stulik Dusan, and James M. Landry. *Infrared Spectroscopy in Conservation Science*. Los Angeles: The Getty Conservation Institute, 1999, p. 68-77.



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## BIBLIOGRAPHY

- Alvarez, Luciano Cedillo, "Stucco: A Report on the Methodology Developed in Mexico," in *In Situ Archaeological Conservation: Proceedings of Meetings, April 6-13, 1986, Mexico*. Los Angeles: The Getty Conservation Institute, 1987, pp. 90-97.
- Bandelier, Adolf F. *The Delight Makers*. New York: Dodd, Mead and Company, 1890.
- \_\_\_\_\_. *Investigations in the Southwest, Part I*. Archaeological Institute of America Papers. Cambridge: John Wilson and Son, 1890.
- \_\_\_\_\_. *Investigations in the Southwest, Part II*. Archaeological Institute of America Papers. Cambridge: John Wilson and Son, 1892.
- Barba, Carlos, Margarita San Andres, Javier Peinado, Maria Isabel Baez and Jaun Luis Baldonado, "A Note on the Characterization of Paint Layers by Transmission Electron Microscopy," in *Studies in Conservation*, Volume 40, No. 3, August 1995, pp. 194-199.
- Baumann, Steven M. "Integrating GIS and Cultural Resources Databases for Archaeological Site Monitoring." *CRM* 22.9 (1999) p.33-35.
- Bishop, Mitchell Hearn and Christopher Gray and Gaetano Palumbo. "New Documentation Technologies at the Getty Conservation Institute." *CRM* 21.5 (1998) 40-41.
- Biswell, S., et al. "GIS and Excavation: A Cautionary Tale from Shepton Mallet, Somerset, England, in *Archaeology and Geographical Information Systems: A European Perspective*, Gary Lock and Zoran Stancic, eds. London: Taylor and Francis, Ltd., 1995.
- Bonhert, Allen S., "The Preservation of Prehistoric Mud Plaster at Mesa Verde National Park," in *6<sup>th</sup> International Conference on the Conservation of Earthen Architecture: Adobe 90 Preprints*. Los Angeles: The Getty Conservation Institute, 1990, pp. 261-265.
- Boyer, Jeffery L., "The House that Juan Built: An Archaeological Perspective on Adobe Analyses," in *6<sup>th</sup> International Conference on the Conservation of Earthen Architecture: Adobe 90 Preprints*. Los Angeles: The Getty Conservation Institute, 1990, pp. 197-203.
- Brody, J.J. *Anasazi and Pueblo Painting*. Albuquerque: University of New Mexico Press, 1991.



- 
- Brookover, William D. and Robert A. Ryan III. "Photogrammetric Recording of Independence Hall." *CRM* 14.3 (1991).
- Brown, Gordon E. "Testing of Concretes, Mortars, Plasters and Stuccos," in *Archaeomaterials*, Vol. 4, No.2, Summer 1990, pp.185-191.
- Burns, John A. "CAD-Photogrammetry: A Powerful Documentation Tool. HABS/HAER Measured Drawings and CAD-Photogrammetry." *CRM* 14.3 (1991).
- Clarke, David L. *Spatial Archaeology*. New York: Academic Press, 1977.
- Cobau, Andreina Costanzi, "Excavated Wall Plasters: Conservation Problems," in *Preventative Measures During Excavation and Site Protection*. Rome: ICCROM, 1986, pp.103-108.
- Columbo, L., M. Danzi and M. Matrotoberto. "Photogrammetric imaging for a Necropolis of the Bronze Age." *Science and Technology for Cultural Heritage*, 6 (2), 1997, p.121-127.
- Cordell, Linda. *Prehistory of the Southwest*. New York: Academic Press, 1984.
- \_\_\_\_\_. *Archaeology of the Southwest, 2<sup>nd</sup> Edition*. New York: Academic Press, 1997.
- Courty, Marie Agnes, Paul Goldberg and Richard Macphail. *Soils and Micromorphology in Archaeology*. Cambridge: Cambridge University Press, 1989.
- Culpepper, R. Brian. "Better Planning Through GIS: Battlefield Management Efforts at CAST." *CRM* 20.5 (1997) p. 32-34.
- Derrick, Michele R., Dusan Stulik, and James M. Landry. *Infrared Spectroscopy in Conservation Science*. Los Angeles: The Getty Conservation Institute, 1999.
- Dix, Linnaea A. "Characterization and Analysis of Prehistoric Earthen Plasters, Mortars, and Paints from Mug House, Mesa Verde National Park, Colorado." Master's Thesis, University of Pennsylvania, 1996.
- Dolinsky, Paul D. "Documenting Diversity: Cultural Resource Management in Hawaii's." *CRM* 15.7 (1992).



- Espinosa, Agustin, "Conservation and Restoration of the Murals of the Temple of the Paintings In Bonampak," in *In Situ Archaeological Conservation: Proceedings of Meetings, April 6-13, 1986, Mexico*. Los Angeles: The Getty Conservation Institute, 1987, pp. 84-89.
- Ford, Bruce, Ian Macleod and Phil Haydock, "Rock Art Pigments for Kimberley Region of Western Australia: Identification of the Minerals and Conversion Mechanisms," in *Studies in Conservation*, Vol. 39, No. 1, February 1994, pp. 57-69.
- French, Pamela, "The Problems of In Situ Conservation of Mudbrick and Mud Plaster," *In Situ Archaeological Conservation: Proceedings of Meetings, April 6-13, 1986, Mexico*. Los Angeles: The Getty Conservation Institute, 1987, pp. 78-83.
- Goff, Stephen, et al. "The Valles/Toledo Caldera Complex, Jemez Volcanic Field, New Mexico," *Annual Review of Earth and Planetary Sciences*, 1990.
- Goren, Yuval and Paul Goldberg, "Petrographic Thin Sections and the Development of Neolithic Plaster Production in Northern Israel," in *Journal of Field Archaeology*, Volume 18, No. 1, Spring 1991, pp. 131-138.
- Gourdin, William Hugh. "A Study of Neolithic Plaster Materials from the Near and Middle East," Master's Thesis, Massachusetts Institute of Technology, 1974.
- Hendron, J.W. "Group M of the Cliff Dwellings, Rooms 1, 2, 3, 4 and 5, Caves 1, 2, 3 and 4, Frijoles Canyon, Bandelier National Monument, New Mexico," 1943.
- Hewett, Edgar Lee. "Antiquities of the Jemez Plateau, New Mexico." Bureau of American Ethnology Bulletin 32. Washington: Government Printing Office, 1906.
- \_\_\_\_\_, and Adolf F. Bandelier. *Indians of the Rio Grande Valley*. Handbooks of Archaeological History. Albuquerque: The University of New Mexico Press, 1937.
- \_\_\_\_\_. *Pajarito Plateau and its Ancient People*, 2<sup>nd</sup> Ed. The University of New Mexico Press, 1953.
- Heiken, Grant *et al.* "The Valles/Toledo Caldera Complex, Jemez Volcanic Field, New Mexico." *Annual Review of Earth and Planetary Sciences*, 1990. Volume 18, p.27-53.





- Huggett, Jeremy. "Integrating Databases and Graphics: A Prelude to Geographical Information Systems." *Archaeological Computing Newsletter* 30 (1992).
- Hurlbert, Dan. "GIS as a Preservation Tool at Shenandoah." *CRM* 21.1 (1998) p. 26-28.
- Johnson, Ian. "Desktop Mapping and Raster GIS: Best of Both Worlds?" in *Theoretical and Methodological Problems*, Amilcare Biettie, et al, eds. A.B.A.C.O Edizioni, 1996, p.4-7.
- Kvamme, K.L. "A View from Across the Water: The North American Experience In Archaeological GIS," in *Archaeology and Geographical Information Systems: A European Perspective*, Gary Lock and Zoran Stancic, eds. London: Taylor and Francis, Ltd., 1995.
- Lagerqvist, Bosse. *The Conservation Information System: Photogrammetry as a Base for Designing Documentation in Conservation and Cultural Resource Management*. Goteborg: Acta Universitatis Gothoburgensis, 1996.
- The Architecture of Social Integration in Prehistoric Pueblos*. Lipe, W.D. and Michelle Hegmon, eds. Cortez, CO: Crow Canyon Archaeological Center, 1989.
- Lister, Robert H. "Stabilization of Frijoles Cave Ruins, Bandelier National Monument, New Mexico," Fiscal Year 1940. Coolidge, AZ: Southwestern Monuments Headquarters, National Park Service, Department of the Interior, 1940.
- Lock, Gary. "GIS or CAD: What's in a name?" *Archaeological Computing Newsletter* 37 (1993), p. 1.
- Marolf, Kristen R. "AutoCAD and Historic Photographs." *CRM* 15.6 (1992).
- Matero, Frank G. and Angelyn Bass, "Orphans of the Storm: The Preservation of Architectural Plasters in Earthen Ruins," in *CRM*, Vol. 17, Issue 4, 1994, pp. 21 26.
- Matero, Frank G., "The Conservation of Plasters in Archaeological Sites," in *CRM*, Vol. 22, Issue 6, 1999, pp. 59-62.
- Mathien, Frances Joan, Charlie R. Steen and Craig D. Allen, eds. *The Pajarito Plateau: A Bibliography*. National Park Service, 1993.



- Mathien, Frances J. and Thomas C. Windes. "The Value of Photographic Documentation in Archaeological Research: A Case Study." *CRM* 12.5 (1989) p.1-5.
- McCarthy, Deirde. "Applying GIS Technologies to CRM." *CRM* 21.5 (1998), p. 34-35.
- Montero, Sergio Arturo, "The Conservation of Archaeological Painting," in *In Situ Archaeological Conservation: Proceedings of Meetings, April 6-13, 1986 Mexico*. Los Angeles: The Getty Conservation Institute, 1987, pp. 98-105.
- Pearson, Colin and B.K. Swartz, Jr., eds. *Rock Art and Posterity: Conserving, Managing and Recording Rock Art*. Melbourne: AURA, 1991.
- Powers, Robert P., and Janet Orcutt, eds. *The Bandelier Archaeological Survey: Volumes I and II*. National Park Service, 1999.
- Provencher, Shaun. "Cultural Landscape Preservation Issues—Tsankawi Mesa, Bandelier National Monument." Master's Thesis, University of Pennsylvania, 1998.
- Reedy, Chandra L., "Thin-Section Petrography in Studies of Cultural Materials," in *Journal of the American Institute for Conservation*, Vol. 33, No. 2, Summer 1994, pp.115-129.
- Rivera, Angelyn. Personal communication with the author, April 11, 2001.
- Rohn, Arthur H. *Rock Art of Bandelier National Monument*. Albuquerque: University of New Mexico Press, 1989.
- Scanning Electron Microscopy in Archaeology*, Sandra L. Olsen, ed. Oxford: B.A.R., 1988.
- Scott, David A., and William D. Hyder, "A Study of Some Californian Indian Rock Art Pigments," in *Studies in Conservation*, Vol. 38, No. 3, August 1993, pp.155-173.
- Silver, Constance, "Analyses and Conservation of Pueblo Architectural Finishes in the American Southwest," in *6<sup>th</sup> International Conference on the Conservation of Earthen Architecture: Adobe 90 Preprints*. Los Angeles: The Getty Conservation Institute, 1990, pp. 176-181.
- Slater, Mary E. "Characterization of Earthen Architectural Surface Finishes from Kiva Q, Cliff Palace, Mesa Verde National Park, Colorado." Master's Thesis, University of Pennsylvania, 1999.



- 
- Smith, Watson. *Kiva Mural Decorations at Awatovi and Kawaik-a*. Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol. 37. Cambridge: Peabody Museum, 1952.
- Stea, David and Mete Turan. *Placemaking: Production of Built Environment in Two Cultures*. Brookfield: Avebury, 1993.
- Steen, Charlie R. "Pajarito Plateau Archaeological Survey and Excavations," Los Alamos Scientific Laboratory, United States Energy Research and Development Administration, 1977.
- Toll, H. Wolcott. *An Analysis of Variability and Condition of Cavate Structures in Bandelier National Monument*. National Park Service, 1995.
- Turney, John Francis, "An Analysis of the Material Taken from a Section of Group M of the Cliffs, Frijoles Canyon, Bandelier National Monument, New Mexico, 1943." Master's Thesis, Adams State College, 1948.
- van Leusen, P. Martijn. "GIS and Archaeological Resource Management: A European Agenda," in *Archaeology and Geographical Information Systems: A European Perspective*, Gary Lock and Zoran Stancic, eds. London: Taylor and Francis, Ltd., 1995.
- Warren, John. "Evaluation, Preparation, Testing and Replacement of Materials," in *Conservation of Earth Structure*. Boston: Butterworth Heinemann, 1999, pp. 99-111.



## **Illustrations**





## Illustrations



Figure 1. Cavates in Frijoles Canyon, Bandelier National Monument. Photograph courtesy Frank G. Matero.



Figure 2. Cavates in Group M. Photograph by author





Figure 3. View of Frijoles Canyon, looking west. Photograph courtesy Frank G. Matero.



**Table 3.11. *Bandelier project chronology.***

Period	Date Range	Rio Grande Periods
1	1150 ( $\pm$ 25) to 1190 ( $\pm$ 20)	Early Coalition
2	1190 ( $\pm$ 20) to 1220 ( $\pm$ 15)	
3	1220 ( $\pm$ 15) to 1235 ( $\pm$ 15)	
4	1235 ( $\pm$ 15) to 1250 ( $\pm$ 20)	
5	1250 ( $\pm$ 15) to 1290 ( $\pm$ 15)	Late Coalition
6	1290 ( $\pm$ 15) to 1325 ( $\pm$ 10)	
7	1325 ( $\pm$ 10) to 1375 ( $\pm$ 25)	Early Classic
8	1375 ( $\pm$ 25) to 1400 ( $\pm$ 25)	
9	1400 ( $\pm$ 25) to 1440 ( $\pm$ 30)	Middle Classic
10	1440 ( $\pm$ 30) to 1525 ( $\pm$ 30)	
11	1525 ( $\pm$ 30) to 1600 ( $\pm$ 30)	Late Classic

Figure 4. Occupations Periods of Frijoles Canyon. *Bandelier Archaeological Survey*, Robert Powers and Janet Orcutt, p. 115.





Figure 5. Cavate M-100. Photograph by author.







Figure 6. Documentation in Cavate M-100, Frijoles Canyon, Bandelier National Monument. Photograph courtesy Frank G. Matero.



91

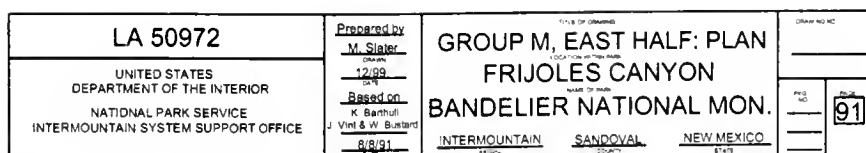
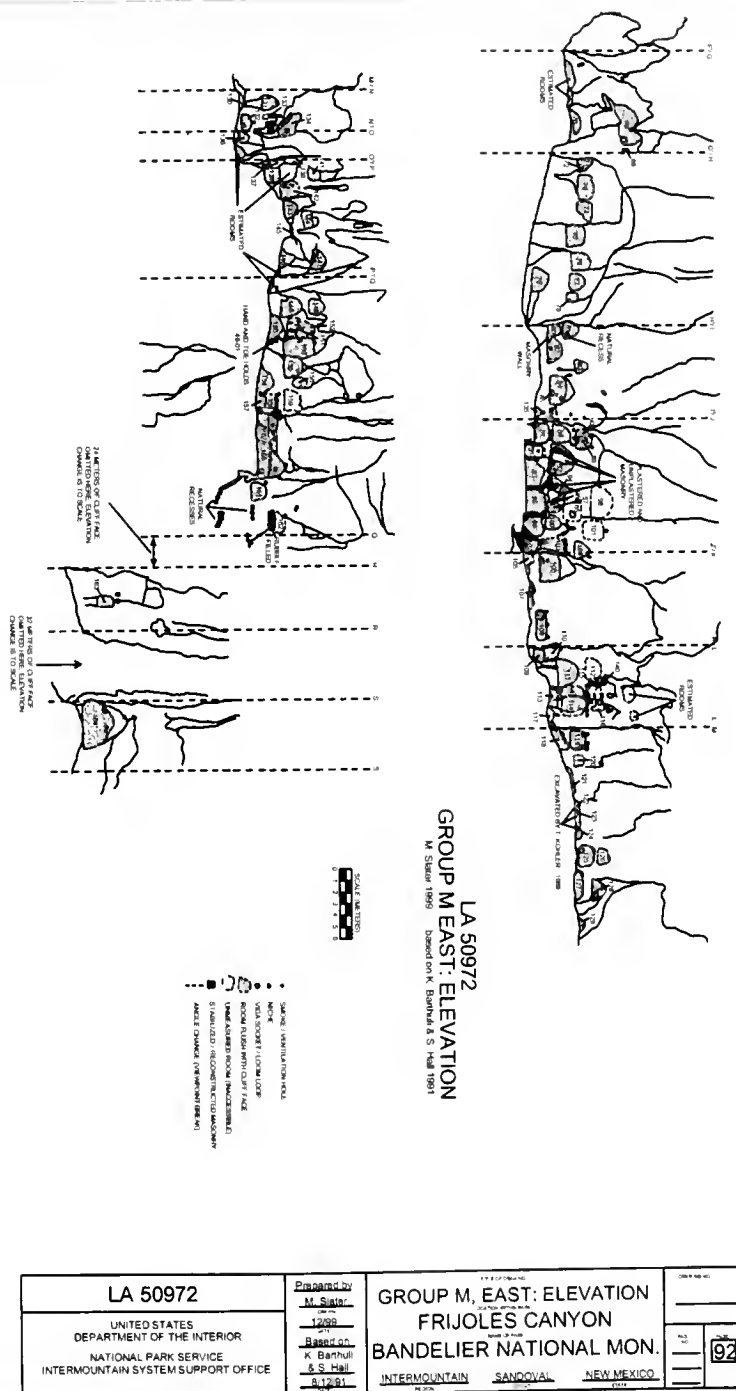




Figure 8. Mary Slater, Bandelier National Monument.





## **Appendix A**

### **Field Manual**





**BAND ARCHITECTURAL CONDITION ASSESSMENT**  
**GLOSSARY OF TERMS**

---

**Area:** Frijoles Canyon

**LA #:** Laboratory of Anthropology site classification number (see plans)

**Group:** classified as Groups A-M (Group B: no # Group C: 50970 Group D: 13665 Group E: 13664 Group M: 50972)

**Room #:** as per plans and elevations

**Date:** date(s) of examination

**Examined by:** surveyor(s) full name

**UNIT SUMMARY DATA:**

**Unit type:** *cavate*- cavities in the canyon walls enclosed on at least three sides that are primarily the result of excavation of the rock

**Plan:** *curvilinear*- rounded  
*D-shaped*- combination of round and straight lines  
*rectilinear*- formed by straight lines  
*indeterminate*- can't tell

**Orientation (facing):** compass directions (N, E, S, W, NE, NW, SE, and SW)

**Associated geological joints:** geological joints defining or intersecting the feature (interior and exterior); indicate yes or no; if yes, include number of joints

**Context:** *isolated*- isolated singular unit with no immediate adjacent neighbors or shared walls, ceilings, floors  
*cluster*- a group of two or more of the same units in close proximity  
*contiguous*- a subcategory of clustered units where the disposition is in levels or where adjacent units share common walls, ceilings, and floors

**Exposure:** *open*- opening is > 50% of entrance wall  
*protected*- opening is < 50% of entrance wall

**Number of entrances:** provide total number of extant entrances (an entrance is an original opening large enough for a person to pass through; not smoke holes or vents). If entrance wall is missing or damaged, and entrances cannot be observed, enter 0 with explanation (i.e. original entrance(s) have been eroded or lost).

**Dimension of entrances:** record height and width of all entrances in meters

**Dimension of cavate:** record cavate dimensions as described below

Curvilinear and D-Shaped	Rectilinear
1. diameter (maximum):	1. length of each wall:
2. diameter perpendicular to center point of max. diameter	2. height from floor to ceiling at center (max):
3. height from floor to ceiling at center (max):	



--	--

**Sketch:** sketch plan and transverse (short axis) and longitudinal (long axis) sections as follows (include dimensions)

**EXAMPLE**

Plan ( <i>indicate geologic joints</i> )	Section ( <i>transverse and longitudinal</i> )

**Cavate building materials:**

*rock*- modification of the living rock, usually through subtractive processes; provide general location (e.g. all walls)

*masonry*- rubble or worked / finished rock units laid dry or wet with mortar; provide general location (e.g. lining smoke hole,, entrance)

**Rock type:** *Tschirege* tuff (gray in color; most cavates in Frijoles Canyon are in the lower unit of the Tschirege)

*Otowi* tuff (tends to be red in color and less consolidated (welded) than the Tshirege member)

**Interior rock surface texture:** *undressed*- no tooling (discernable on exposed rock surface)  
*pointed*- gouged, groove tooling  
*pecked*- pounded, dimple tooling  
*obscured*- concealed or damaged



**Original masonry type:**     pertains to unstabilized, original masonry  
                                  *wet-laid-* with mortar between the stones  
                                  *dry-laid-* without mortar between the stones

**Original masonry stone type:**     *Tschirege* tuff (gray)  
  *Otowi* tuff (red)  
  *basalt* (tends to be dark in color and very welded)

**Original mortar type:** self-explanatory

**Masonry stabilization:** indicate yes or no based on records and/or visual observation

**Stabilization mortar type:** *earth*  
  *modified earth-* earth with additive such Portland cement (gray), calcium aluminate  
(pink), or acrylic  
  *Portland cement*

**Stabilization date(s):**            indicate if known; cite reference

**Dimension of masonry walls:** record length and width (top and bottom) of all walls in metric

**Features:** circle all that apply; definitions as per Toll (see attached)



## SURFACE FINISHES

**General scheme for interior walls and ceiling:** self-explanatory

### Wall Finishes

**Predominant wall finish type:**

- extruded smooth plaster*-mortar that extends beyond masonry courses and onto the surface of the wall, covering at least 3/4 of each masonry unit; does not apply to plaster on tuff; is often used as a surface leveling and filling technique; thickness can vary
- applied plaster*- a discrete layer or layers of plaster greater than 1mm thick applied over masonry or tuff, and which has been worked to create a continuous, relatively uniform surface
- wash*- a discrete layer or layers of thinly applied earthen finish, usually less than 1mm thick, which is applied directly over plaster, masonry, or tuff
- sooted rock*- soot deposited on the tuff (without earthen finishes)
- unfinished*- the intentional absence of a finish

**Surface area of existing wall finishes:** calculate surface area in m<sup>2</sup> (total length multiplied by the average height of wall's finish)

**Maximum # of visible layers:** maximum number of plaster and wash layers visible with the naked eye or with low magnification (soot not counted)

**Presence of sooted layers between earthen finishes:** indicate yes or no

**General color(s):** circle all visible colors

**Finish scheme:** this combination of fields describes the spatial coverage of the finishes and the grouping of elements that compose the surface scheme (the uppermost visible layer); this set of attributes relates to the original intent and execution of the finish application, as opposed to the existing remnants

A. first describe the coverage as either:

- partial*- the presence of one or more finish elements (see below) in combination with unfinished rock; the wall is not fully finished (including sooting)
- full*- the presence of one or more finish elements covering the entire wall; the wall is fully finished
- indistinguishable*- can't tell

B. then describe the grouping of elements as either :

- simple*- the presence of only one element defining the surface scheme
- complex*- the presence of more than one element defining the surface scheme

C. lastly, indicate the types of elements (circle all that apply):

- full wall*- a layer or layers of earthen finish or soot that entirely cover the surface
- dado*- as band of earthen finish or soot on the lower third or half of a wall that is finished differently than the rest of the wall
- field*- a band of earthen finish or soot on the upper third or half of a wall that is finished differently than the rest of the wall
- aura*- a finish of earth or soot around a doorway or other opening in the cavate; it is usually a different color than the rest of the wall
- floor band*- a band of earthen finish or soot applied to the lower 10-20cm of the wall; it can also be an extension of the material used to finish the floor
- embellishment*- a discrete detail or pattern of designs applied, incised, or impressed in earthen finish, soot, or rock

**Embellishment(s):** indicate if embellishments are present or absent; if present, provide the following descriptive information:

**general number of embellishments in plaster and in rock:** separate values for each

**general description:** this should include

- motifs (the type of representation that the embellishment most closely represents, such as *zoomorphic*- having the form of an animal or bird)





*anthropomorphic*- having the form of a human  
*geometric*- having rectilinear or curvilinear lines

- application method used to create the embellishments such as:
  - incised*- the small-scale incision of a motif or pattern into the finish or sooted tuff, created with a sharp tool, usually after the finish has dried
  - applied*- the small-scale surface application of a wash, applied as a motif or pattern with the aid of a tool such as a yucca paint brush, stick, or fingertips to the wet or dry finish
  - impressed*- the small-scale impression of a motif or pattern into the finish while it is still plastic and before it has dried; observed impressions include: maize cobs, potsherds, stick ends, fingertip and handprints
- general colors such as red / brown / tan / white / gray / blue / green

**Finish texture:** *striated*-stippled, parallel grooves in finish  
*finger and handprints*-finger and hand impressions

**Earlier finish schemes:** indicate yes or no and then briefly describe

**Ceiling :** same definitions as Wall Finishes

### **Floor**

**Materials:** self-explanatory

**Maximum # of visible layers:** maximum number of plaster visible with the naked eye or with low magnification on site

**General description:** describe layering sequence and include comment on existence and intactness of features such as a firepit, floor ridge, large floor level niche, loom anchors, metate rest, etc...

## **EXISTING CONDITIONS**

Assess the type and severity of condition of the cavate interior walls, ceiling, floor, and exterior. Severity is the percentage of surface area affected for the rock and finish, except for loss, which is the percentage of total original. Assign a value of **0= Insignificant (<10%)**; **1= Low (10-25%)**; **2= Moderate (26-50%)**; **3= High (>50%)** and then multiply by 2 where indicated. At the end of the table, record the values for loss and the total sum of the other condition values.

### **Conditions:**

*loss*-absence of original fabric based on total original extent of rock, masonry or finishes

*partial loss*- loss of one or more layers from the existing finish, leaving earlier layers exposed; can occur only in multi-layered finishes

*disintegration/friability*-granular disaggregation of the rock or finishes

*detachment*- voids between finish layers, at the rock/plaster interface, or within the rock; includes *delamination / flaking* (the separation and lifting of discreet layers of finishes from each other; flaking is active deterioration and loss of thin fragments which are not necessarily confined to discrete layers as in delamination); *blistering* (localized, small scale swelling and/or rupturing of the finish layer; tends to occur in thin plaster layers) and; *blind voids* (voids or separation between plaster layers or at the rock/plaster interface which have no visible edges but which can be detected when a hollow sound is produced by tapping on the surface)

*rock undercutting*- the undermining of rock so as to leave an overhanging portion in relief; usually occurs on the ceiling near the entrance

*structural cracking*- major (>1cm deep and/or 50cm long) linear discontinuities in the rock or masonry including geologic joints

*non-structural cracking*- fractures of variable length and orientation in the rock or finishes that do not appear to be the result of structural settlement or movement or joints

*map cracking*-fine pattern cracking over an area of the finishes; cracks usually penetrate only through a single finish layer



*staining*- discoloration of the rock or finishes caused by the addition of a substance such as animal excrement or other (does not apply to oxidation or soot)  
*mechanical damage*- discrete areas of damage or loss caused by an external impact or force  
*graffiti / vandalism*- modern, intentionally inscribed or applied markings on the rock or finishes  
*visitor abrasion*-disaggregation or erosion resulting from visitor contact; usually around entrances  
*biological growth*- the presence of microflora (algae, fungi, and/or lichen) on the surface  
*vegetation*-presence of higher plant forms or the roots thereof

**General condition comments:** indicate which conditions appear to pose the greatest threat(s) to the resource

## TREATMENT RECOMMENDATIONS

**Treatment urgency:** *high priority*- intervention necessary within 1-2 years to mitigate existing active damage and possible future deterioration  
*medium priority*- intervention necessary within 2- 5 years to mitigate existing active damage and possible future deterioration  
*low priority*- intervention necessary within 5-10 years to mitigate existing active damage and possible future deterioration

### Proposed treatment actions:

*none*- self-explanatory  
*backfill ( full)*- fully fill a cavate with granular material (sand or soil) as a long-term preservation action; this treatment requires detailed written and graphic documentation prior to filling  
*backfill (partial)*- protect earthen floors and fragile floor features by temporarily covering them with sand and geotextiles to a shallow depth  
*cover with slash*- obscure the entrance with slash (vegetation) to deter visitor use  
*restrict access*- close to visitor use  
*finishes conservation (grouting / cleaning / reattachment / edging / other)*- stabilize and/or clean prehistoric and historic architectural finishes; work must be undertaken by a professional conservator  
*graffiti mitigation*- obscure graffiti by infilling or inpainting  
*animal or insect control*- eliminate animal and/or insect invasion (i.e. by filling rodent holes; screening areas to deter bee or wasp nesting)  
*drainage control*- prevent water from infiltrating or flowing directly onto the resource; actions may include installation of silicone drip lines, diversionary berms, protective shelters, etc...  
*masonry stabilization*- stabilize wall or features; actions may include replacing stones, repointing, and crack stabilization  
*monitor*- photograph and conduct regular visual comparative assessments to determine rate of change over time; assessment should make use of past documentation including historic photographs, reports, drawings, etc... pertaining to the area

**Total approximate area to be treated:** in metric

**Safety hazard:** indicate if public health risks exist due to dangerous conditions resulting from past or actively occurring deterioration; if so, describe the threats

**Comments:** prioritize treatment actions

## PREVIOUS DOCUMENTATION

Cite previous and current reports, publications, photographs, drawings, etc.

Conduct photographic comparison between the image and now; estimate percentage of loss and/or type of change in appearance



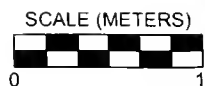
## **Appendix B**

### **Annotated Drawings**

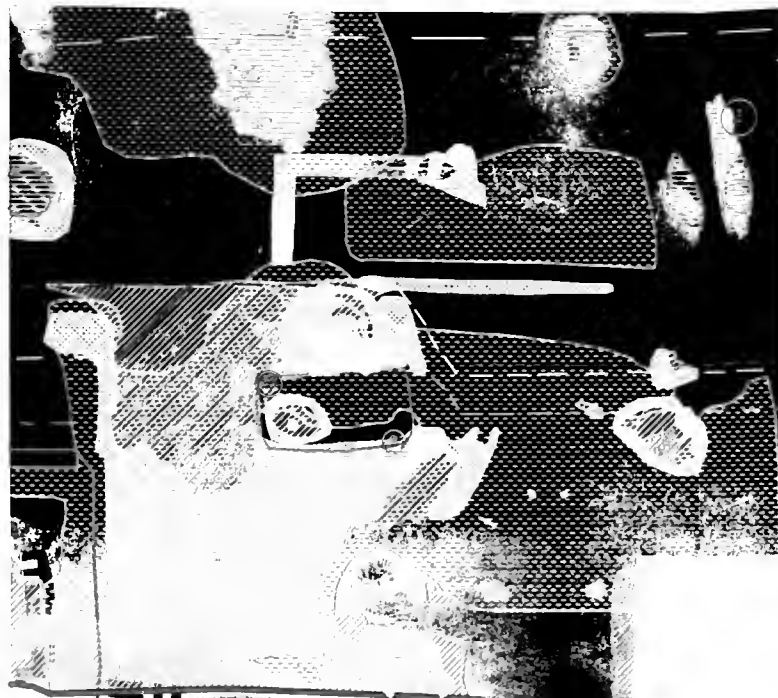


- Archfeature
- Total Loss
- Loss-partial
- Crack-finish
- Crack-map
- Crack-masonry
- Displacement
- Blistering
- Delamination
- Detachment
- Disaggregation
- Mechanical-damage
- Surface-carbon
- Surface-deposits
- Surface-salts
- Biological-growth
- Vegetation
- Color change
- Graffiti
- Embellishments
- Dado A
- Dado B
- Dado C
- Dado D

Notes: Total loss, partial loss, detachment and delamination.



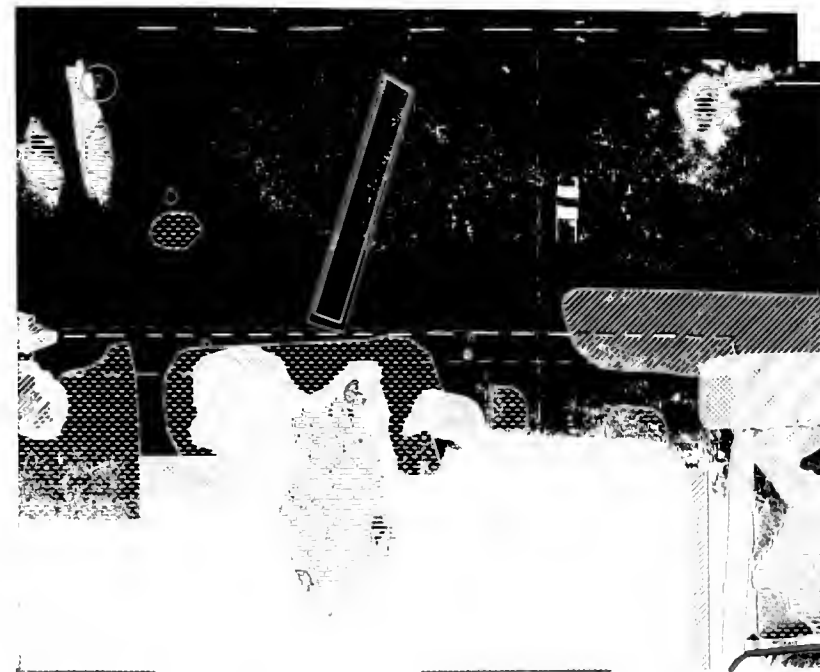
South Wall



North Wall



West Wall



East Wall

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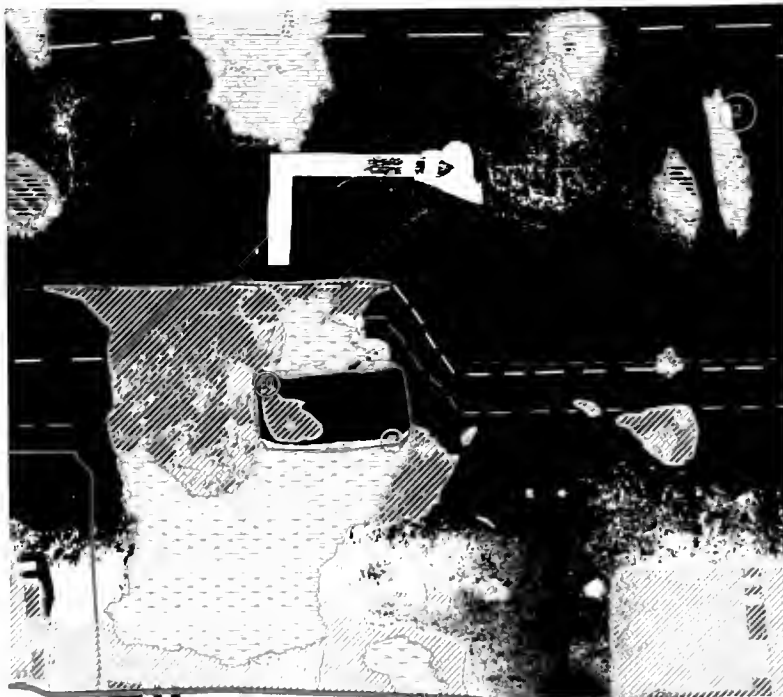
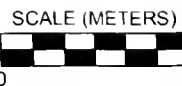
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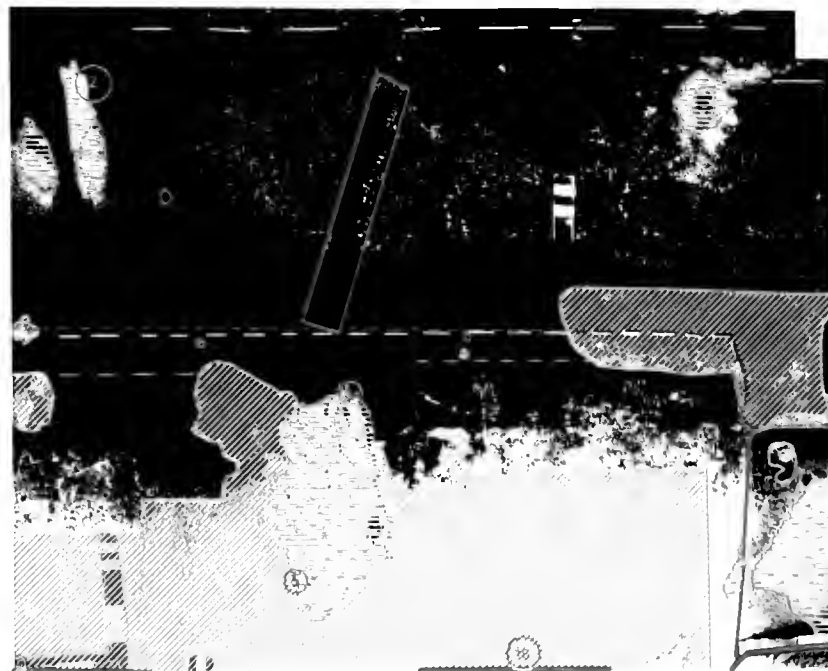


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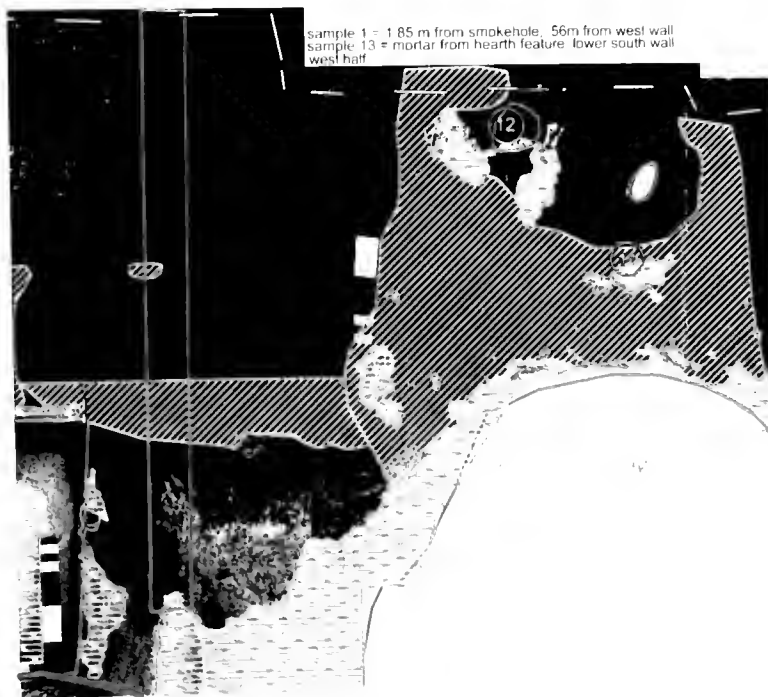
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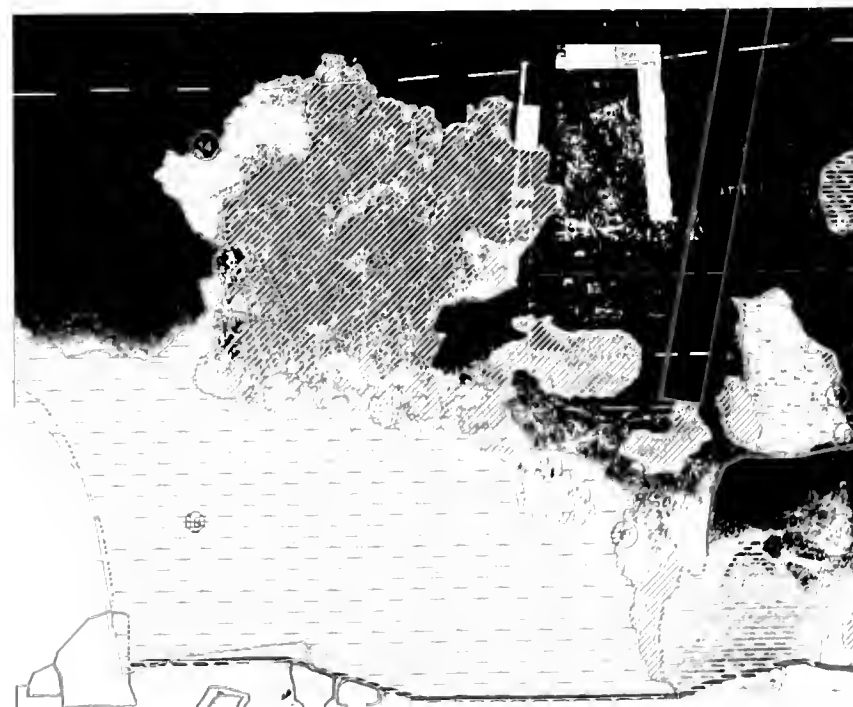
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East Wall



South Wall



West Wall

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







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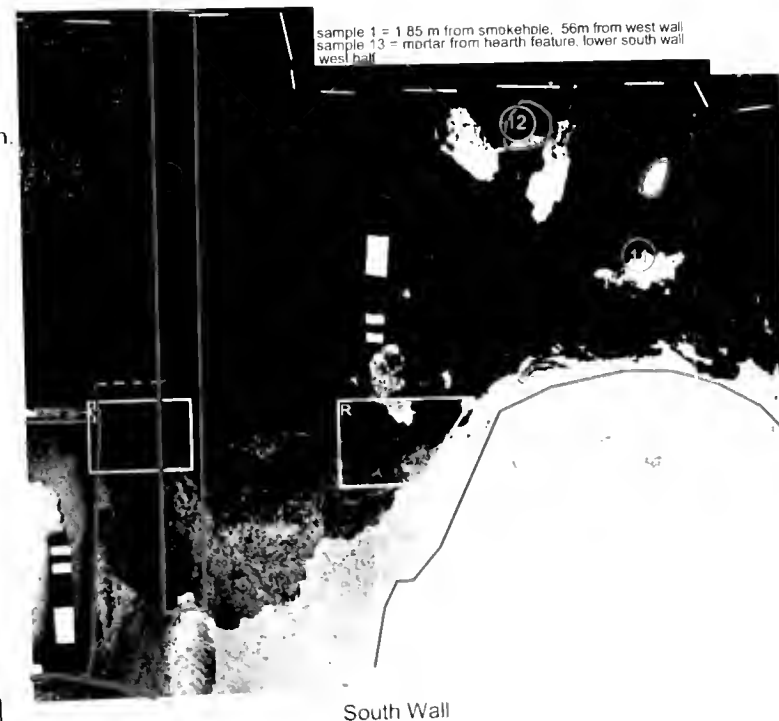
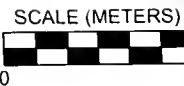
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-  Displacement
-  Blistering
-  Delamination
-  Detachment
-  Disaggregation
-  Mechanical-damage
-  Surface-carbon
-  Surface-deposits
-  Surface-salts
-  Biological-growth
-  Vegetation
-  Color change
-  Graffiti
-  Embossments
-  Dado A
-  Dado B
-  Dado C
-  Dado D

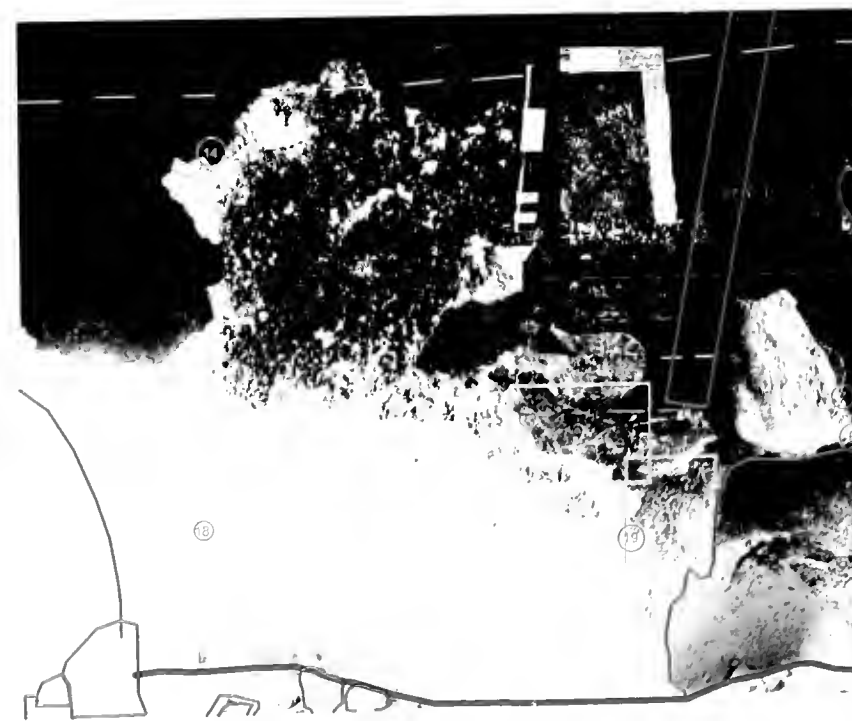
Notes: Finish and map cracking,  
detachment and delamination.



South Wall



North Wall



West Wall



East Wall

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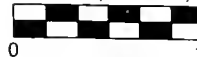


- Architecture
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- Surface-salts
- Biological-growth
- Vegetation
- Color change
- Graffiti
- Embellishments
- Dado A
- Dado B
- Dado C
- Dado D

Notes: Embellishments and graffiti.



SCALE (METERS)



North Wall



East Wall



South Wall



West Wall

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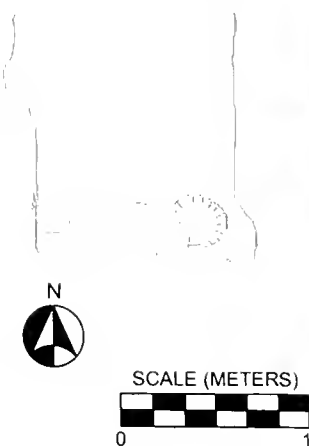
DOCUMENTATION TIME:  
ELSA LARSEN, ST  
ELSA LARSEN, ST  
GLENDA FRED

DATE RECORDED:  
JUNE 2000  
DATE PRINT:  
2000



- Archfeature
- Total Loss
- Loss-partial
- Crack-finish
- Crack-map
- Crack-masonry
- Displacement
- Blistering
- Delamination
- Detachment
- Disaggregation
- Mechanical-damage
- Surface-carbon
- Surface-deposits
- Surface-salts
- Biological-growth
- Vegetation
- Color change
- Graffiti
- Embellishments
- Dado A
- Dado B
- Dado C
- Dado D

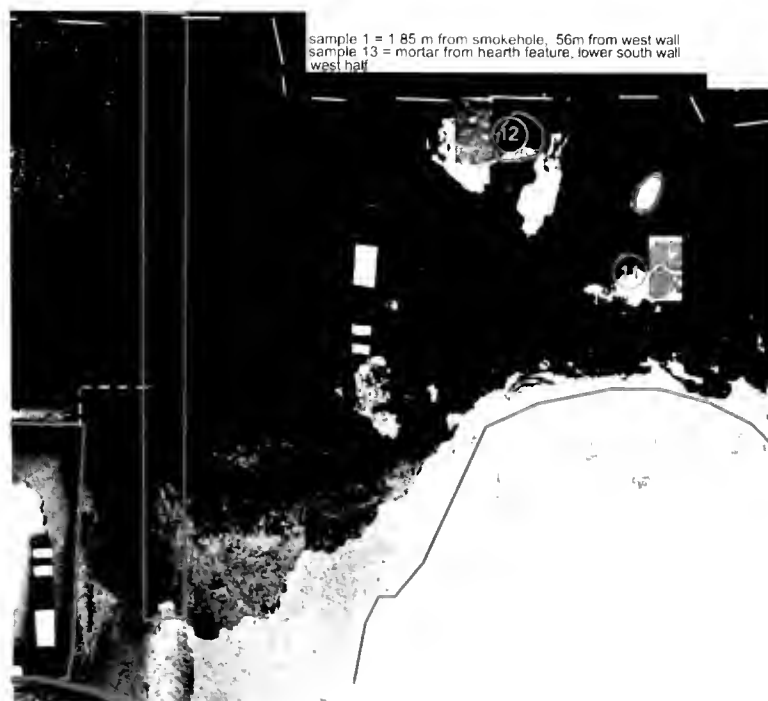
Notes: Sample locations.



North Wall



East Wall



South Wall



West Wall

CAVATE M-100, GROUP M, FRIJOLE CANYON

LOS ALAMOS, NEW MEXICO

BANDELIER NATIONAL MONUMENT

SPONSORED BY  
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FIELD SUPERVISORS  
ANGELYN RIVERA AND MARY SLATER

THESE RECORDS  
PROF. FRANK G. MATERO, UNIVERSITY OF PENNSYLVANIA

THESE RECORDS  
ROBY GAUTHIER, PARK ARCHAEOLOGIST, BANDELIER NATIONAL MONUMENT

ARCHITECTURAL CONSERVATION LABORATORY  
GRADUATE PROGRAM IN HISTORIC PRESERVATION  
UNIVERSITY OF PENNSYLVANIA

DOCUMENTATION  
KATHLEEN CORREY  
ELIZABETH JOHNSON  
GLENN FRED

SITE RECORDING  
JUNE 2000  
DATA ENTRY  
2000





## **Appendix C**

### **Embellishment Survey**

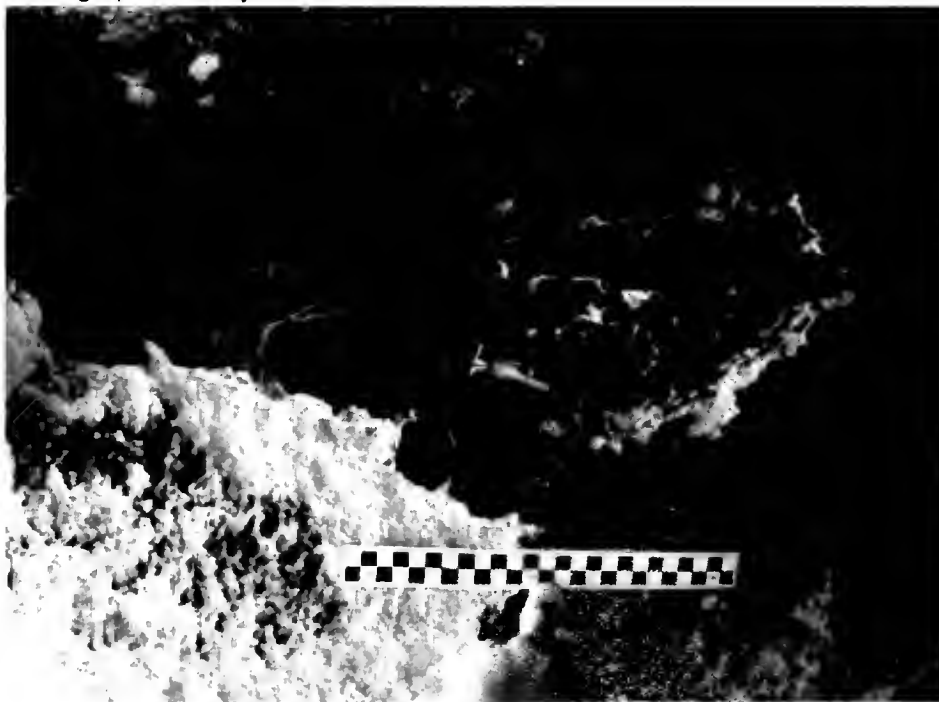


Matthew J. Liebmann  
June 24, 2000  
West Wall, Sectors 4  
and 6. Includes panels  
A and B.  
Photograph courtesy of  
Matthew J. Liebmann



Figure C.1

Figure C.2 Matthew J. Leibmann. June 24, 2000. West Wall, Sector 4, Panel A.  
Photograph courtesy of Matthew J. Leibmann.





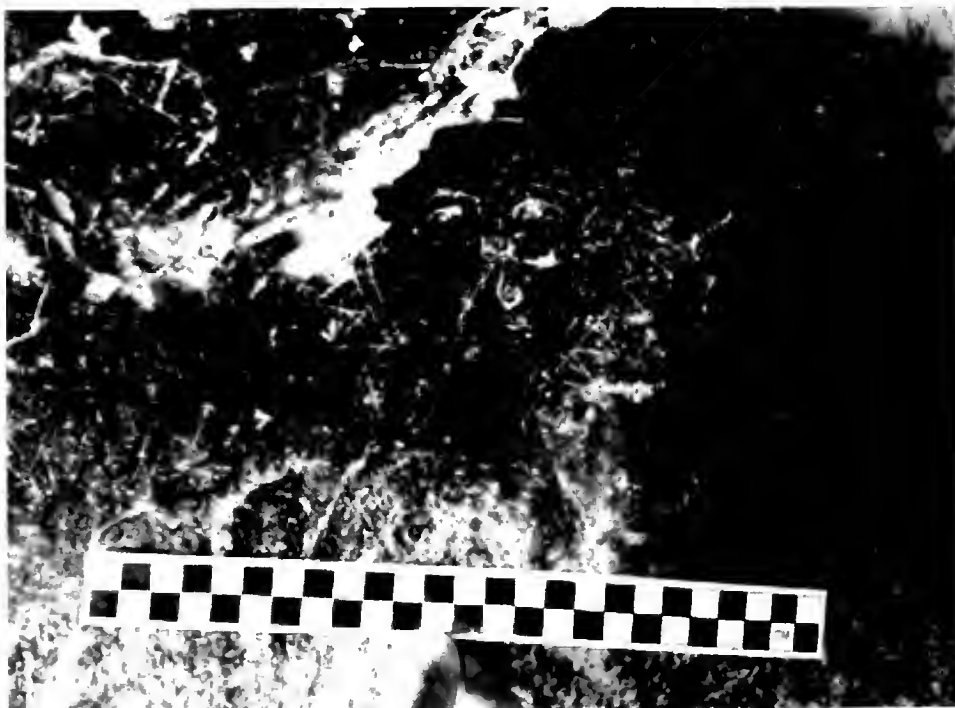


Figure C.3 Matthew J. Liebmann, June 24, 2000. West Wall, Sector 6, Panel B.  
Photograph courtesy of Matthew J. Liebmann.

Figure C.4 Matthew J. Leibmann. June 24, 2000 West Wall, Sector 6, Panel C  
Photograph courtesy of Matthew J. Leibmann.







Figure C.5 Charles Steen, April 1943. North Wall, Sectors 8 and 10, Panels F, G and H. Bandelier Negative Number 00201A

Figure C.6 Glenn Haynes, June 6, 1951. North Wall, Sectors 8 and 10, Panels F, G, and H. Bandelier Negative Number 00203A







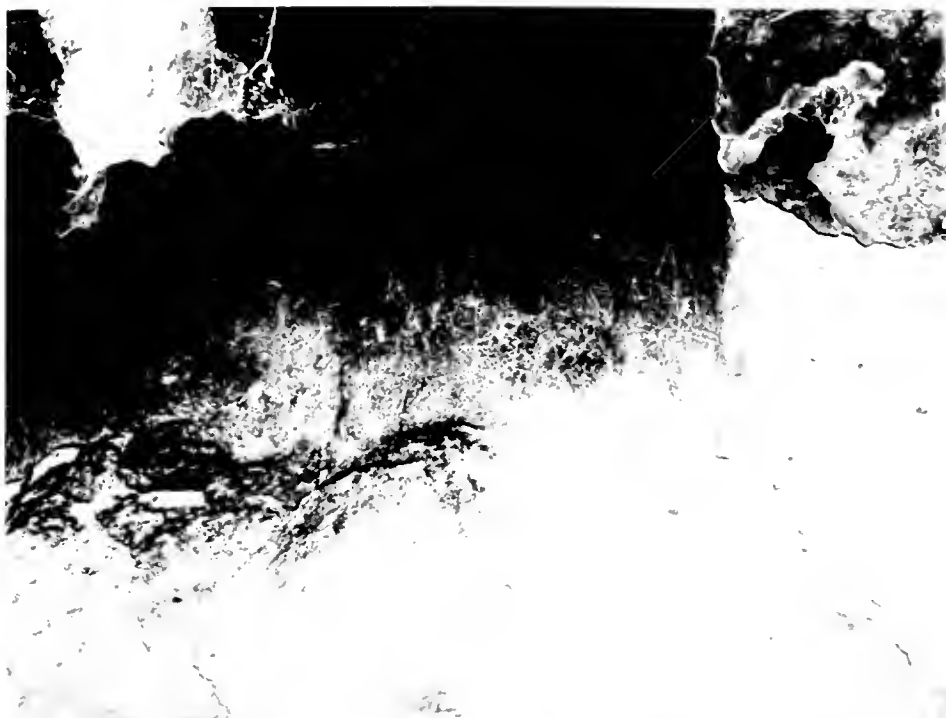


Figure C.7 Glenn Haynes, June 5, 1951. North Wall, Sector 8, Panel E. Bandelier Negative Number 00204A. Photograph courtesy of Bandelier National Monument.

Figure C.8 Matthew J. Liebmann, June 24, 2000. North Wall, Sector 8, Panel E. Photograph courtesy of Matthew J. Liebmann.

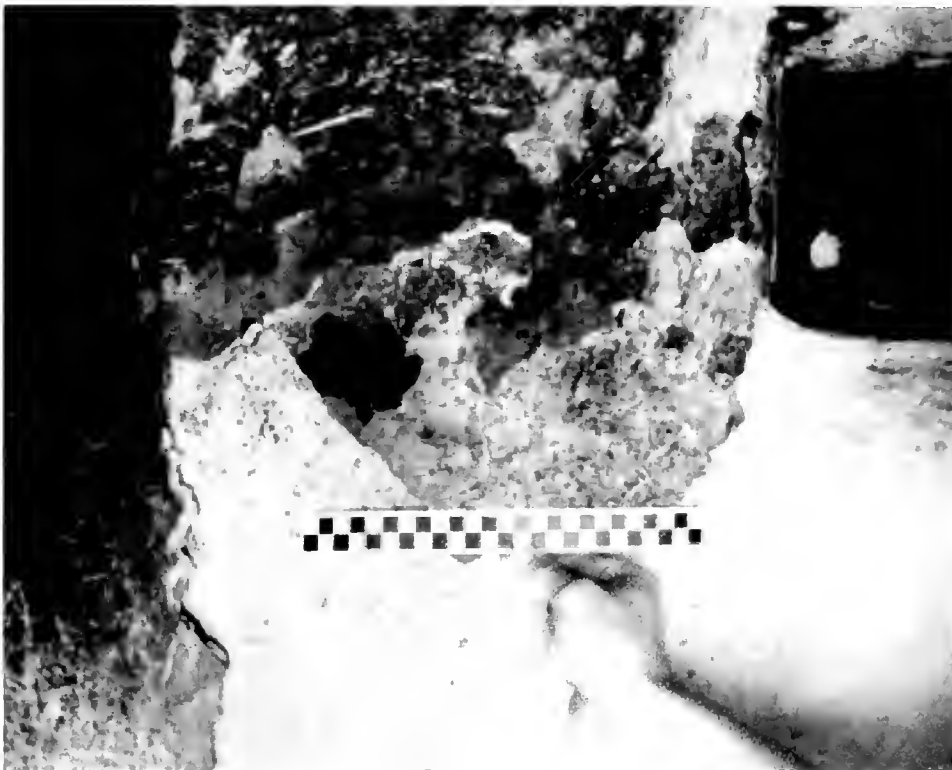






Figure C.9 Matthew J. Liebmann, June 24, 2000 Detail, Sector 8, Panel E.  
Photograph courtesy of Matthew J. Liebmann.

Figure C.10 Matthew J. Liebmann, June 24, 2000 Sector 10 Photograph  
courtesy of Matthew J. Liebmann







Figure C.11 Matthew J. Liebmann, June 24, 2000. Detail, Sector 10, Panel I.  
Photograph courtesy Matthew J. Liebmann.

Figure C.12 Matthew J. Liebmann, June 24, 2000. Detail, Sector 10, Panel G.  
Photograph courtesy Matthew J. Liebmann.

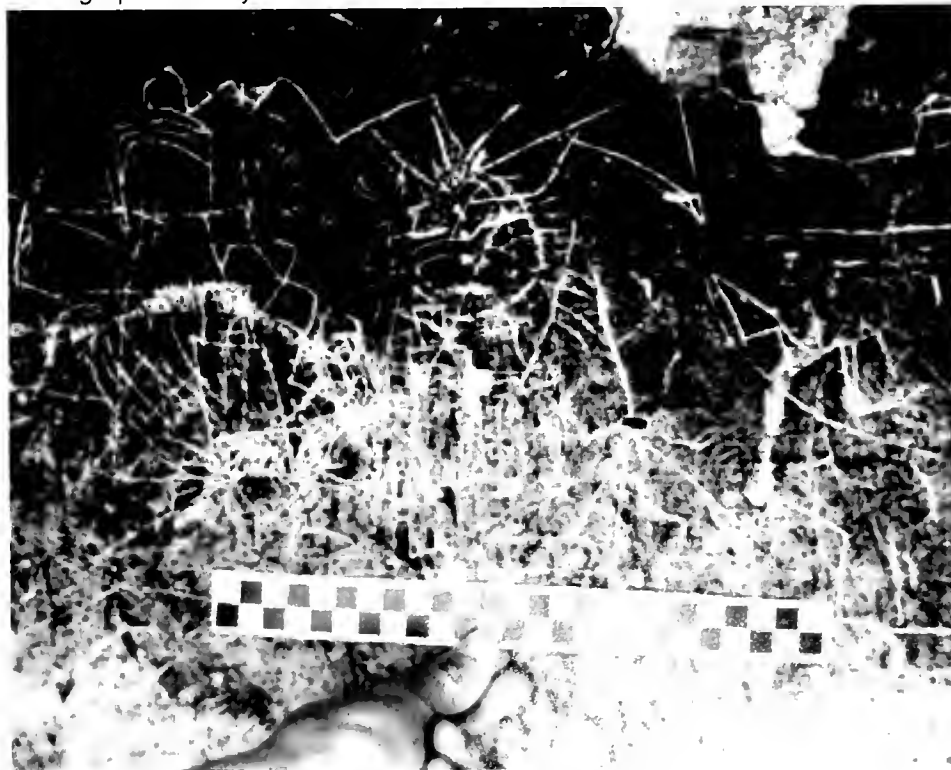






Figure C.13 Charles Steen, April 1943. East Wall, Sector 14, Panels L, M and N. Bandelier Negative Number 00200A. Photograph courtesy Bandelier National Monument.

Figure C.14 Charles Steen, April 1943. East Wall, Sector 12, Panel P. Bandelier Negative Number 00198A. Photograph courtesy of Bandelier National Monument.









Figure C.15 Kenneth Chapman, 1916. East Wall, Sector 14, Panel M. Bandelier Negative Number 04502. Photograph courtesy Bandelier National Monument.



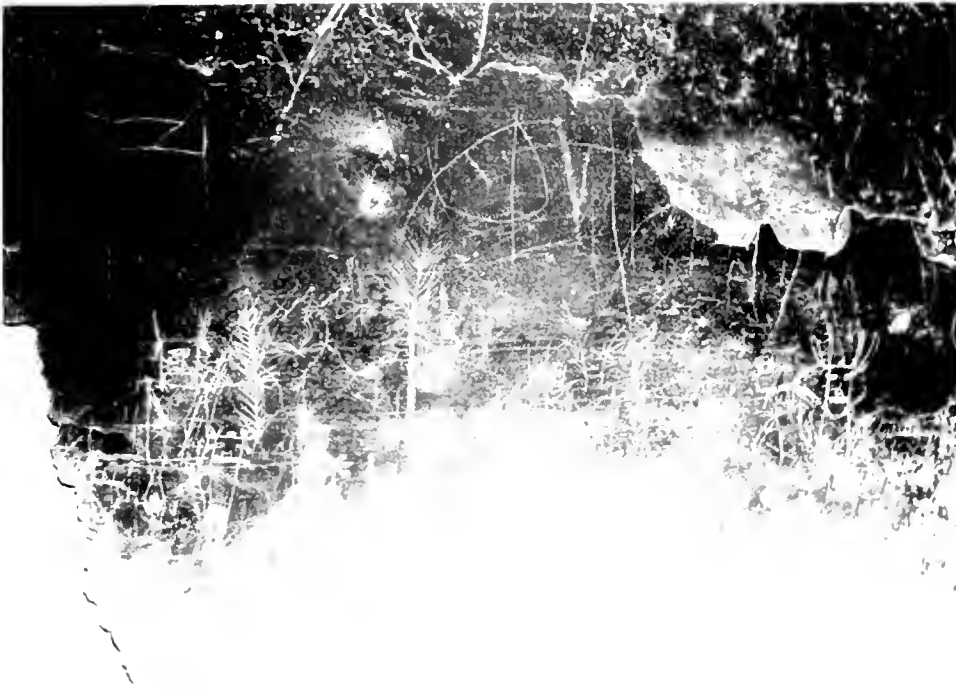


Figure C.16 Glenn Haynes, June 6, 1951. East Wall, Sectors 14 and 16, Panels L, M, N, O and P. Bandelier Negative Number 00202A. Photograph courtesy Bandelier National Monument.

Figure C.17 Matthew J. Liebmann, June 24, 2000. Sector 14 and 16, Panels N, O and P. Photograph courtesy of Matthew J. Liebmann.







Figure C.18 and C.19  
Matthew J. Liebmann, June 24,  
2000. Sectors 14 and 16, Panels  
L, M, N, O and P. Photographs  
courtesy Matthew J. Liebmann.







Figure C.20 Matthew J. Liebmann, June 24, 2000 Detail, Sector 14, Panel P.  
Photograph courtesy of Matthew J. Liebmann.

Figure C.21 Matthew J. Liebmann, June 24, 2000. Detail, Sector 14, Panel P.  
Photograph courtesy of Matthew J. Liebmann.

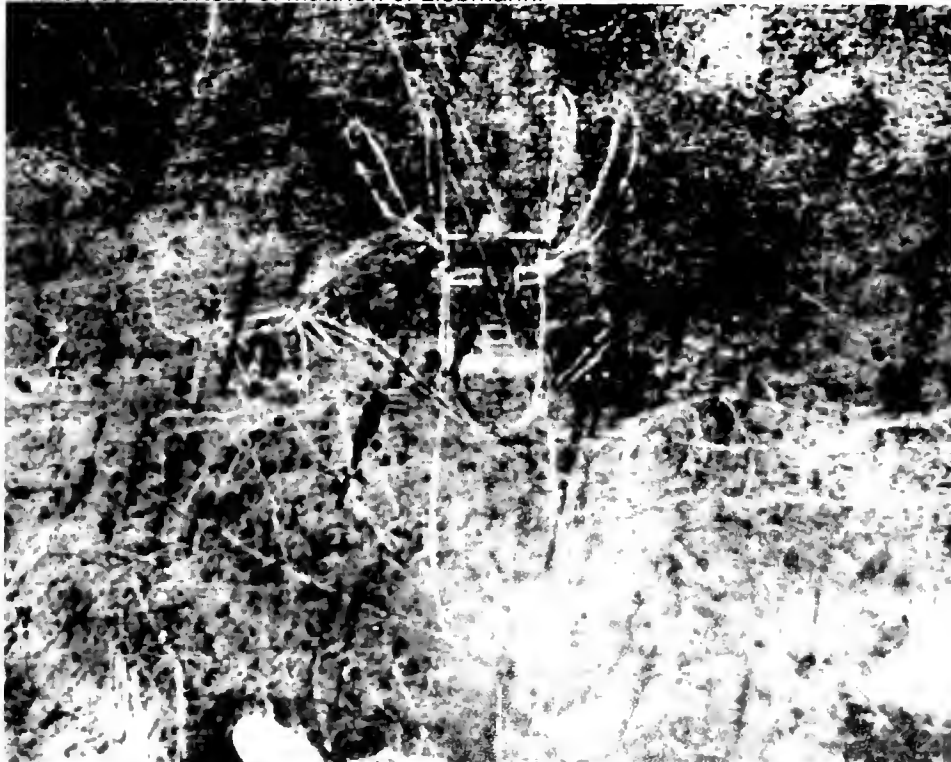








Figure C.22 Matthew J. Liebmann, June 24, 2000 Detail, Sector 12, Panel N  
Photograph courtesy of Matthew J. Liebmann.

Figure C.23 Matthew J. Liebmann, June 24, 2000 Detail, Sector 12, Panel O.  
Photograph courtesy of Matthew J. Liebmann.





Figure C.24 and C.25  
Matthew J. Liebmann,  
June 24, 2000.  
Sector 18, Panel R.  
Photographs courtesy  
Matthew J. Liebmann







Figure C.26 Matthew J. Liebmann, June 24, 2000. Sector 18, Panel R. Photograph courtesy of Matthew J. Liebmann.

Figure C.27

Charles Steen, April 1943. Location Unknown. This photograph is attributed to M-100, however this may be inaccurate. There is no evidence in M-100 of this embellishment. Bandelier Negative Number 00199A. Photograph courtesy Bandelier National Monument.







Figure C.28  
No Photographer, No Date  
Bandelier Negative Number 03677A



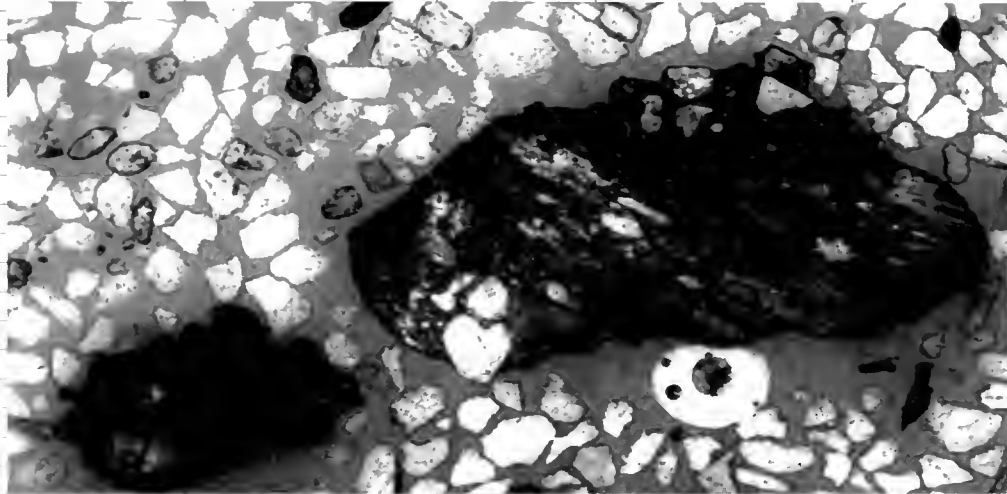


## **Appendix D**

### **Thin Section Micromorphology**



Ceiling  
1.85 m from smoke hole  
.56 m from west wall  
123

	<i>type</i>	<i>measurement</i>	<i>surface texture</i>	<i>coarse fine ratio</i>	<i>layer color</i>	<i>matrix color</i>	<i>coarse fraction color</i>	<i>coarse fraction shape</i>	<i>coarse fraction sorting</i>	<i>boundary</i>		
1	soot	85µm			10 R 4/1 dark reddish gray					sharp		
2	tuft	2.7mm								sharp		
 <p>Sample 100.01 is true soot accumulation. There is debris trapped in the soot.</p>												



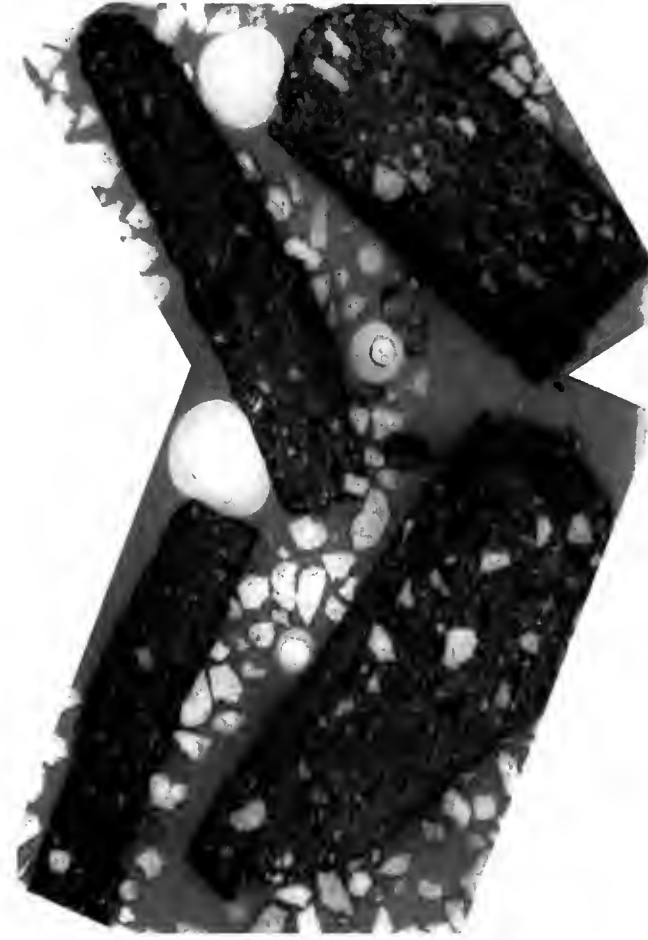
East Wall,  
North Half  
.60 m from floor  
.29 m from  
north wall  
124

[illegible]



Sample BAND 100.02  
Cavate M-100  
Frijoles Canyon  
Bandelier National Monument  
New Mexico, USA

East Wall,  
North Half  
1.60 m from floor  
.29 m from  
north wall  
125

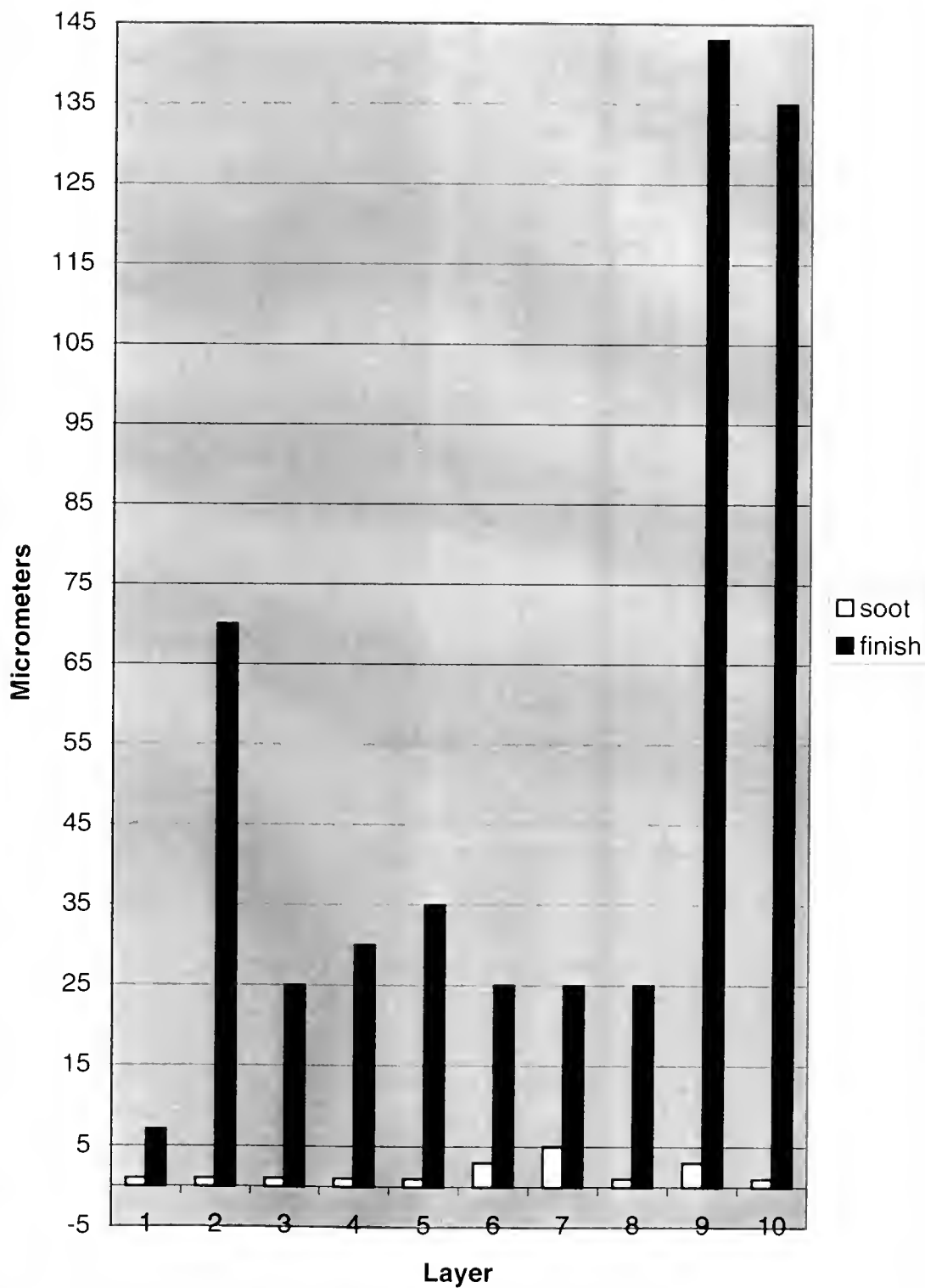


There are large inclusions in layers 2, 4, 6, 8, 10, 18,  
and 20.





## Sample BAND M-100.02





Sample BAND 100.03 Sample BAND 100.04  
Cavate M-100  
Frijoles Canyon  
Bandelier National Monument  
New Mexico, USA

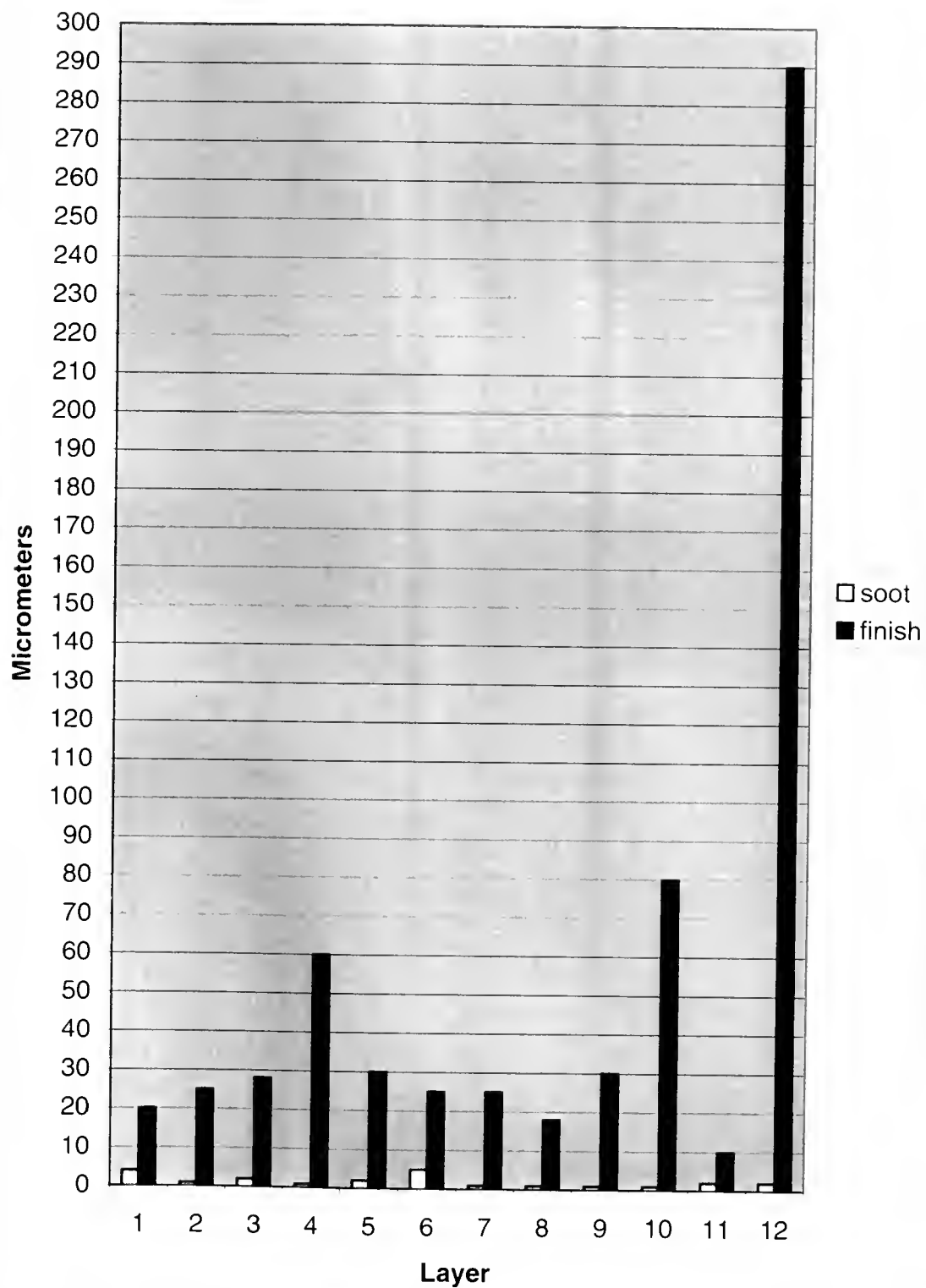
East Wall,  
North Half  
.87 m from floor  
.75 m from  
north wall  
127

	type	measurement	surface texture	coarse fine ratio	layer color	matrix color	coarse fraction color	coarse fraction shape	coarse fraction sorting	boundary
1	soot	4µm			soot					sharp
2	wash	20µm	moderately rough	50% : 50%	2.5 Y 3/1 very dark gray	2.5Y 3/2 very dark grayish brown	GLEY 1 7/N light gray	spherical subrounded	even	fuzzy
3	soot	1µm			soot					fuzzy
4	wash	25µm	wavy	50% : 50%	2.5Y 3/1 very dark gray	2.5 Y 3/2 very dark grayish brown	GLEY 1 7/N light gray	spherical subrounded	uniform	fuzzy
5	soot	2µm			soot					sharp
6	wash	28µm	moderately rough	40% : 60%	7.5 YR 6/2 pinkish gray	7.5 YR 5/1 gray	GLEY 1 7/N light gray	spherical subrounded	even	fuzzy
7	soot	1µm			soot					fuzzy
8	wash	60µm	moderately rough	30% : 70%	7.5 YR 4/2 dark grayish brown	7.5 YR 5/1 gray	GLEY 1 7/N light gray	spherical rounded	uniform	fuzzy
9	soot	2µm			soot					fuzzy
10	wash	30µm	slightly rough	30% : 70%	7.5 YR 4/2 dark grayish brown	7.5 YR 5/1 gray	GLEY 1 7/N light gray	spherical subrounded	uniform	fuzzy
11	soot	5µm			soot					fuzzy
12	wash	25µm	weakly serated	30% : 70%	7.5 YR 3/2 dark brown	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	subspherical subrounded	uniform	fuzzy
13	soot	1µm			soot					fuzzy
14	wash	25µm	slightly rough	40% : 60%	7.5 YR 3/2 dark brown	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	subspherical subrounded	mostly uniform, some clusters	fuzzy
15	soot	1µm			soot					sharp
16	wash	18µm	weakly mamillated	40% : 60%	5 YR 3/4 dark reddish brown	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	subspherical subrounded, tabular subangular	uniform	sharp
17	soot	1µm			soot					sharp
18	wash	30µm	slightly rough	40% : 60%	7.5 YR 3/2 dark brown	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	spherical subrounded	uniform	sharp
19	soot	1µm			soot					sharp
20	plaster	80µm	wavy	30% : 70%	7.5 YR 5/1 gray	2.5 Y 4/1 dark gray	GLEY 1 7/N light gray	subspherical subrounded	uniform	sharp
BREAK										
21	soot	2µm			soot					sharp



East Wall,  
North Half  
87 m from floor  
.75 m from  
north wall  
128



**Sample BAND M-100.03 and 100.04**





Sample BAND 100.05  
Cavate M-100  
Frijoles Canyon  
Bandelier National Monument  
New Mexico, USA

East Wall,  
North Half  
.32 m from floor  
.63 m from  
north wall  
130

	<i>type</i>	<i>measurement</i>	<i>surface texture</i>	<i>coarse fine ratio</i>	<i>layer color</i>	<i>matrix color</i>	<i>coarse fraction color</i>	<i>coarse fraction shape</i>	<i>coarse fraction sorting</i>	<i>boundary</i>
1	soot	3µm			soot					sharp
2	wash	15µm	slightly rough	40% : 60%	10 YR 5/1 gray	10 YR 6/2 light brownish gray	GLE Y 1 7/N light gray	subspherical subrounded	uniform	fuzzy
3	soot	1µm			soot					fuzzy
4	wash	45µm	moderately rough	30% : 70%	10 YR 4/1 dark gray	10 YR 6/2 light brownish gray	GLE Y 1 7/N light gray	spherical subrounded	uniform	fuzzy
5	soot	4µm			soot					fuzzy
6	wash	18µm	wavy	20% : 80%	2.5 Y 5/2 grayish brown	10 YR 6/2 light brownish gray	GLE Y 1 7/N light gray	spherical subangular	uniform	fuzzy
7	soot	1µm			soot					sharp
8	wash	5µm	wavy	20% : 80%	2.5 Y 5/1 gray	10 YR 6/2 light brownish gray	GLE Y 1 7/N light gray	spherical subrounded	uniform	sharp
9	soot	1µm			soot					sharp
10	wash	18µm	slightly rough	30% : 70%	7.5 YR 5/2 brown	10 YR 6/2 light brownish gray	GLE Y 1 7/N light gray	subspherical subrounded	uniform	sharp
11	soot	1µm			soot					fuzzy
12	wash	31µm	moderately rough	30% : 70%	2.5 Y 5/1 gray	10 YR 6/2 light brownish gray	GLE Y 1 7/N light gray	subspherical subangular	even	fuzzy
13	soot	2µm			soot					fuzzy
14	wash	12µm	moderately rough	30% : 70%	2.5 Y 5/1 gray	10 YR 6/2 light brownish gray	GLE Y 1 7/N light gray	spherical subrounded	uniform	fuzzy
15	soot	2µm			soot					fuzzy
16	wash	6µm	moderately rough	40% : 60%	7.5 YR 5/2 brown	10 YR 5/1 gray	GLE Y 1 7/N light gray	subspherical subrounded	uniform	fuzzy
17	soot	1µm			soot					fuzzy
18	wash	42µm	slightly rough	40% : 60%	7.5 YR 4/2 brown	10 YR 5/1 gray	GLE Y 1 7/N light gray	subspherical subrounded	uniform	fuzzy
19	soot	1µm			soot					fuzzy
20	wash	32µm	slightly rough	40% : 60%	7.5 YR 4/2 brown	10 YR 4/1 dark gray	GLE Y 1 7/N light gray	spherical subrounded	uniform	fuzzy
21	soot	2µm			soot					fuzzy
22	wash	27µm	moderately rough	40% : 60%	10 YR 4/2 dark gray	10 YR 4/1 dark gray	GLE Y 1 7/N light gray	spherical subrounded	clustered	fuzzy

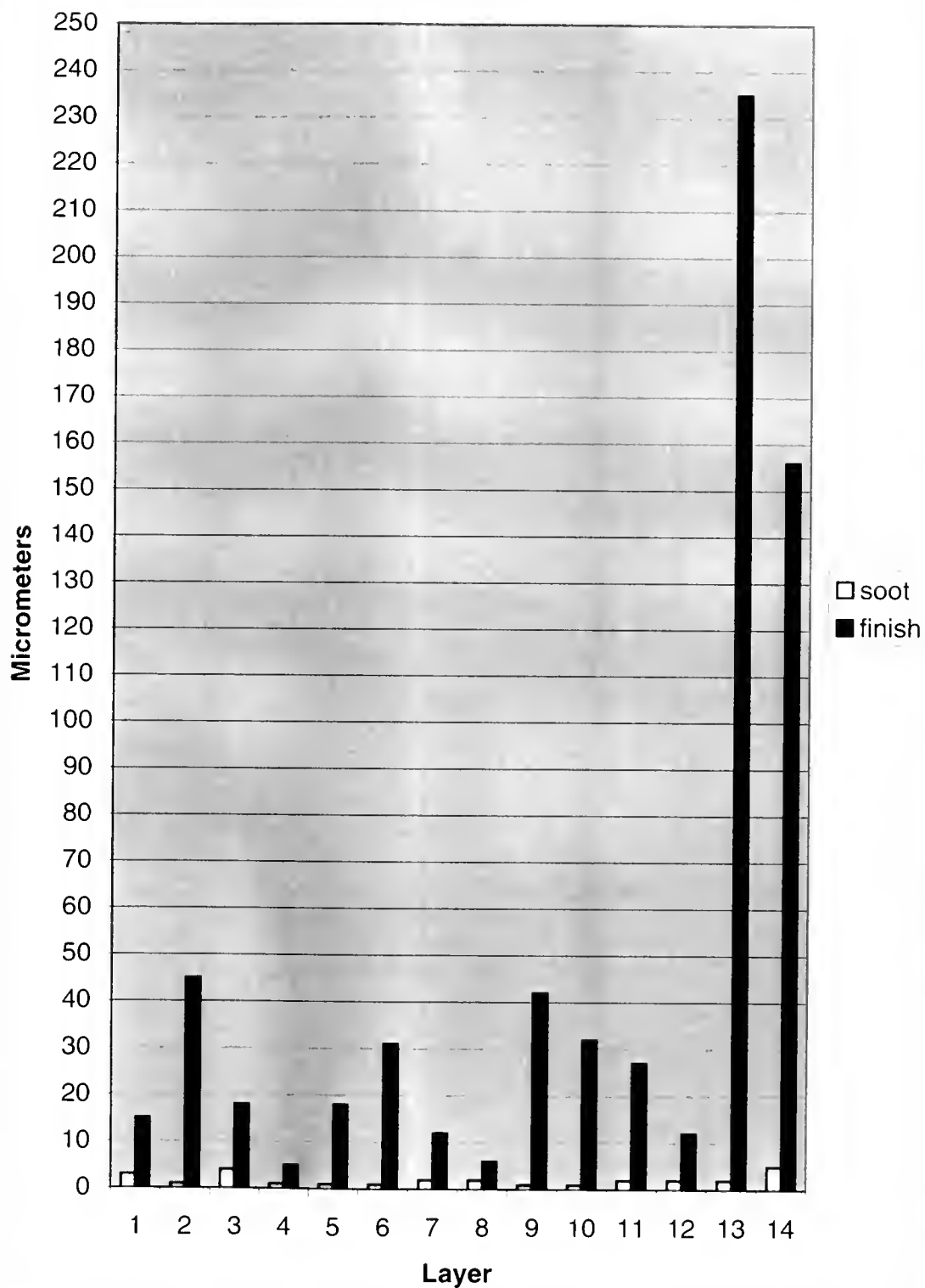


**Sample BAND 100.05**  
**Cavate M-100**  
**Frijoles Canyon**  
**Bandelier National Monument**  
**New Mexico, USA**

East Wall,  
North Half  
.32 m from floor  
.63 m from  
north wall  
131

[illegible]



**Sample BAND M-100.05**



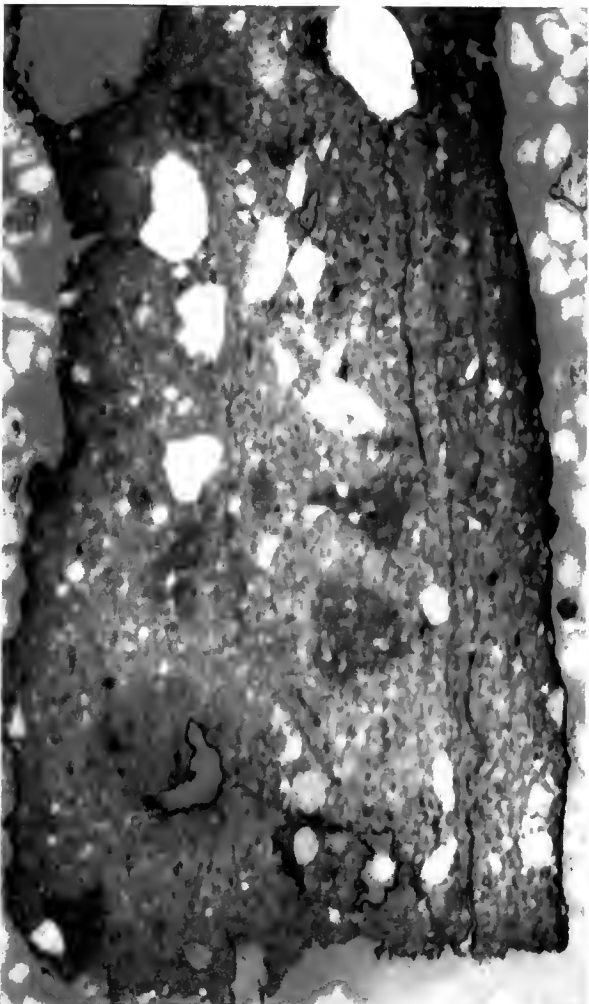
West Wall,  
North Half  
.78 m from floor  
.41 m from  
west wall  
133

[illegible]





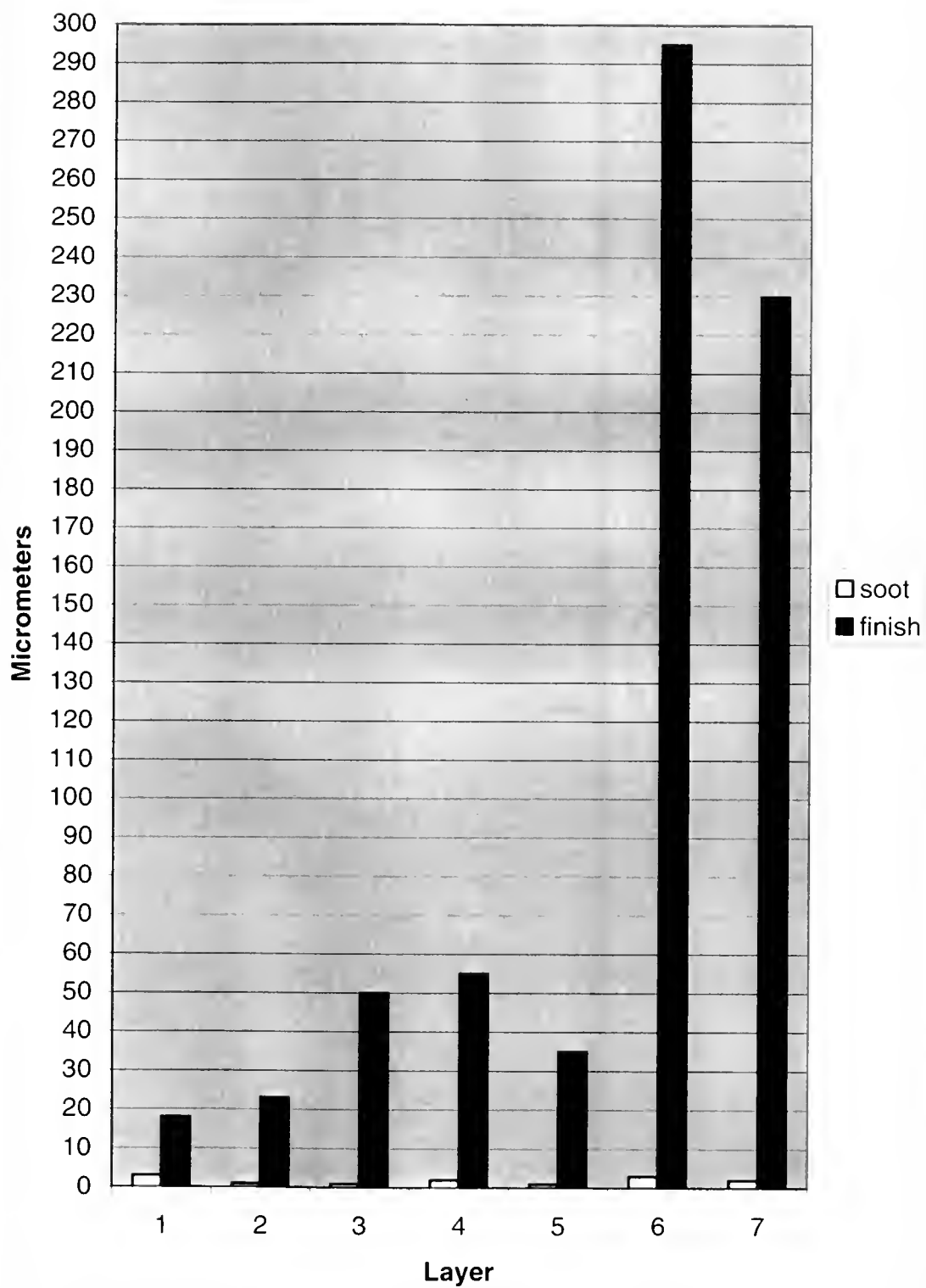
Sample BAND 100.06  
Cavate M-100  
Frijoles Canyon  
Bandelier National Monument  
New Mexico, USA



West Wall,  
North Half  
.78 m from floor  
.41 m from  
west wall  
134

There are large inclusions present  
in layers 2, 4, 10, 12, and 14.



**Sample BAND M-100.06**



Sample BAND 100.07  
Cavate M-100  
Frijoles Canyon  
Bandelier National Monument  
New Mexico, USA

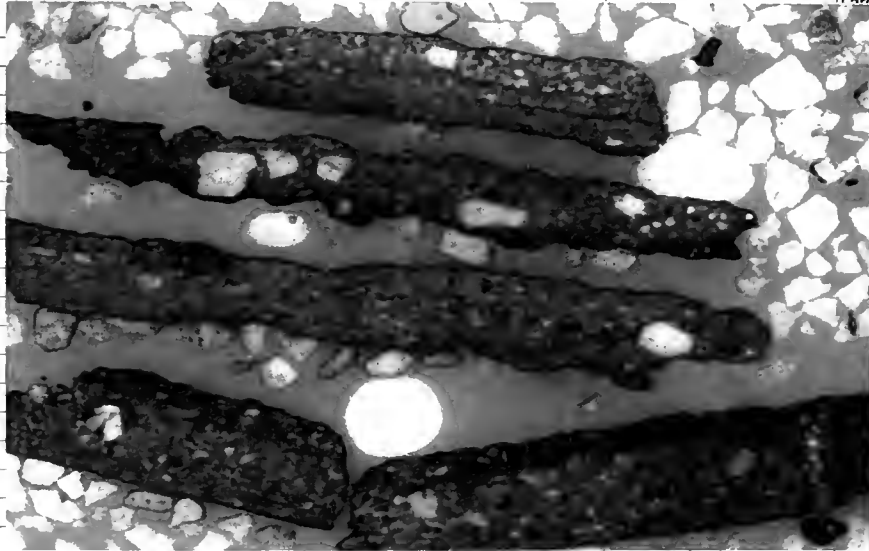
West Wall,  
North Half  
.87 m from floor  
.44 m from  
west wall  
136

	<i>type</i>	<i>measurement</i>	<i>surface texture</i>	<i>coarse fine ratio</i>	<i>layer color</i>	<i>matrix color</i>	<i>coarse fraction color</i>	<i>coarse fraction shape</i>	<i>coarse fraction sorting</i>	<i>boundary</i>
1	soot	2µm			soot					sharp
2	wash	50µm	moderately rough	40% : 60%	2.5 Y 3/1 very dark gray	2.5 3/2 very dark grayish brown	GLEY 1 7/N light gray	spherical subrounded	uniform—very well sorted	sharp
3	soot	1µm			soot					fuzzy
4	wash	35µm	moderately rough	30% : 70%	2.5 Y 4/1 dark gray	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	spherical subrounded	uniform—very well sorted	fuzzy
5	soot	2µm			soot					sharp
6	wash	40µm	slightly rough	30% : 70%	2.5 Y 3/1 very dark gray	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	subspherical subrounded	uniform	sharp
BREAK										
7	soot	2µm			soot					sharp
8	plaster	1.05mm	very rough	50% : 50%	2.5 Y 3/1 very dark gray	7.5 YR 3/1 very dark gray	GLEY 1 7/N light gray	subspherical subrounded	uniform	sharp
9	soot	3µm			soot					sharp
BREAK										
10	wash	50µm	slightly rough	40% : 60%	7.5 YR 4/1 dark gray	7.5 5/2 brown	GLEY 1 7/N light gray	subspherical subangular	uniform	fuzzy
11	soot	3µm			soot					fuzzy
12	wash	25µm	moderately rough	30% : 70%	2.5 Y 4/1 dark gray	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	tabular subrounded	even with some clusters	fuzzy
13	soot	1µm			soot					fuzzy
14	wash	34µm	moderately rough	30% : 70%	2.5 Y 4/1 dark gray	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	spherical subrounded	uniform, some clusters	fuzzy
BREAK										
15	soot	1µm			soot					sharp
16	wash	50µm	moderately rough	40% : 60%	10 YR 3/1 very dark gray	7.5 YR 3/1	GLEY 1 7/N light gray	spherical subangular, tabular angular	even	sharp
17	soot	1µm			soot					fuzzy
18	plaster	80µm	moderately rough	50% : 50%	10 YR 4/1 dark gray	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	subspherical subrounded	even	fuzzy
19	soot	2µm			soot					fuzzy



**Sample BAND 100.07**  
**Cavate M-100**  
**Frijoles Canyon**  
**Bandelier National Monument**  
**New Mexico, USA**

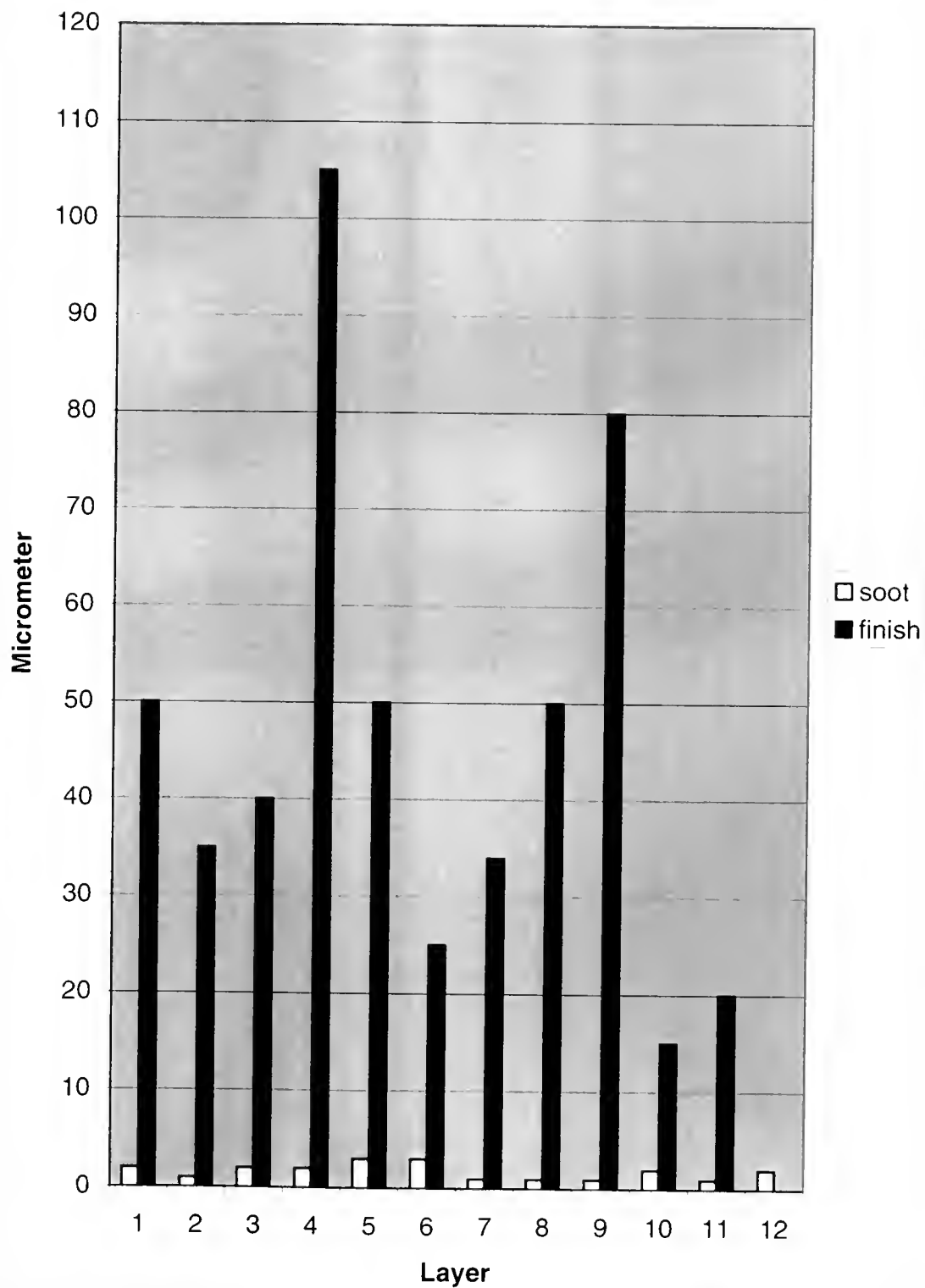
West Wall,  
North Half  
.87 m from floor  
.44 m from  
west wall  
137

20	wash	15µm	moderately rough	50% : 50%	10 YR 4/1 dark gray	10 YR 4/1 dark gray	GLEY 1 7/N light gray	subspherical subrounded	even	sharp
21	soot	1µm			soot					sharp
22	wash	20µm	moderately rough	35% : 65%	2.5 Y 3/2 very dark grayish brown	7.5 YR 4/2 brown	GLEY 1 7/N light gray	subspherical subrounded	uniform	sharp
23	soot	2µm			soot					sharp
 <p>Large inclusions are present in layers 2, 8, 10, and 18.</p>										





## Sample BAND M-100.07

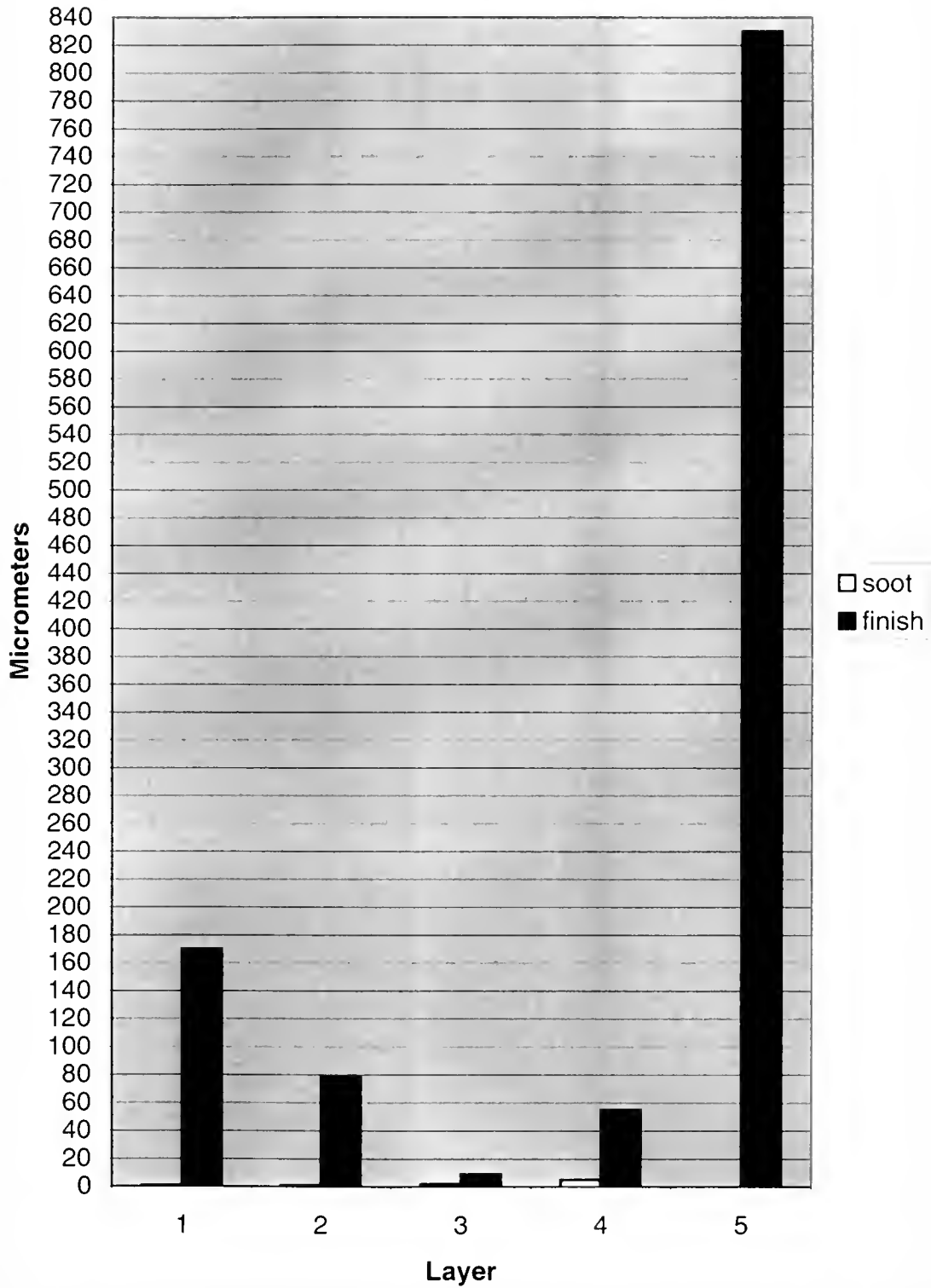




West Wall,  
South Half  
.86 m from floor  
1.32 m from  
west wall  
139

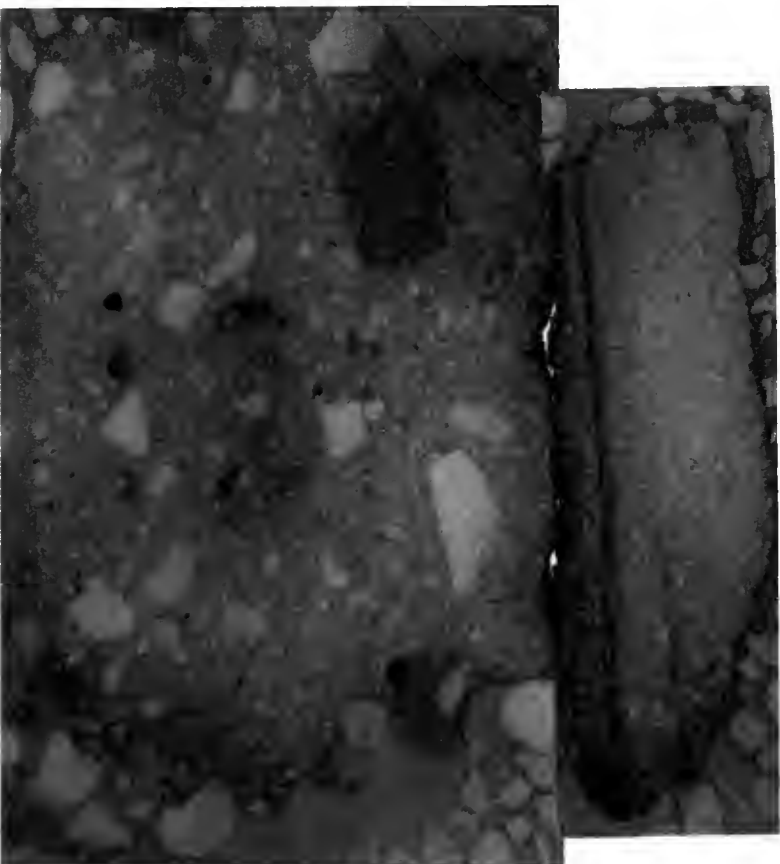
A black and white photograph showing a dark, irregularly shaped object, possibly a piece of wood or stone, resting on a light-colored, textured surface. The object has a lighter, rectangular patch in the center. The surface it lies on appears to be made of small, light-colored stones or pebbles.



**Sample BAND M-100.09**



Sample BAND 100.09  
Cavate M-100  
Frijoles Canyon  
Bandelier National Monument  
New Mexico, USA



Large inclusions present in layer  
9. This sample was broken, and  
has been digitally reconstructed.

Lower North Wall,  
West Half  
Bottom (Floor) of  
Niche  
.80 m from floor  
.86 m from west wall  
141





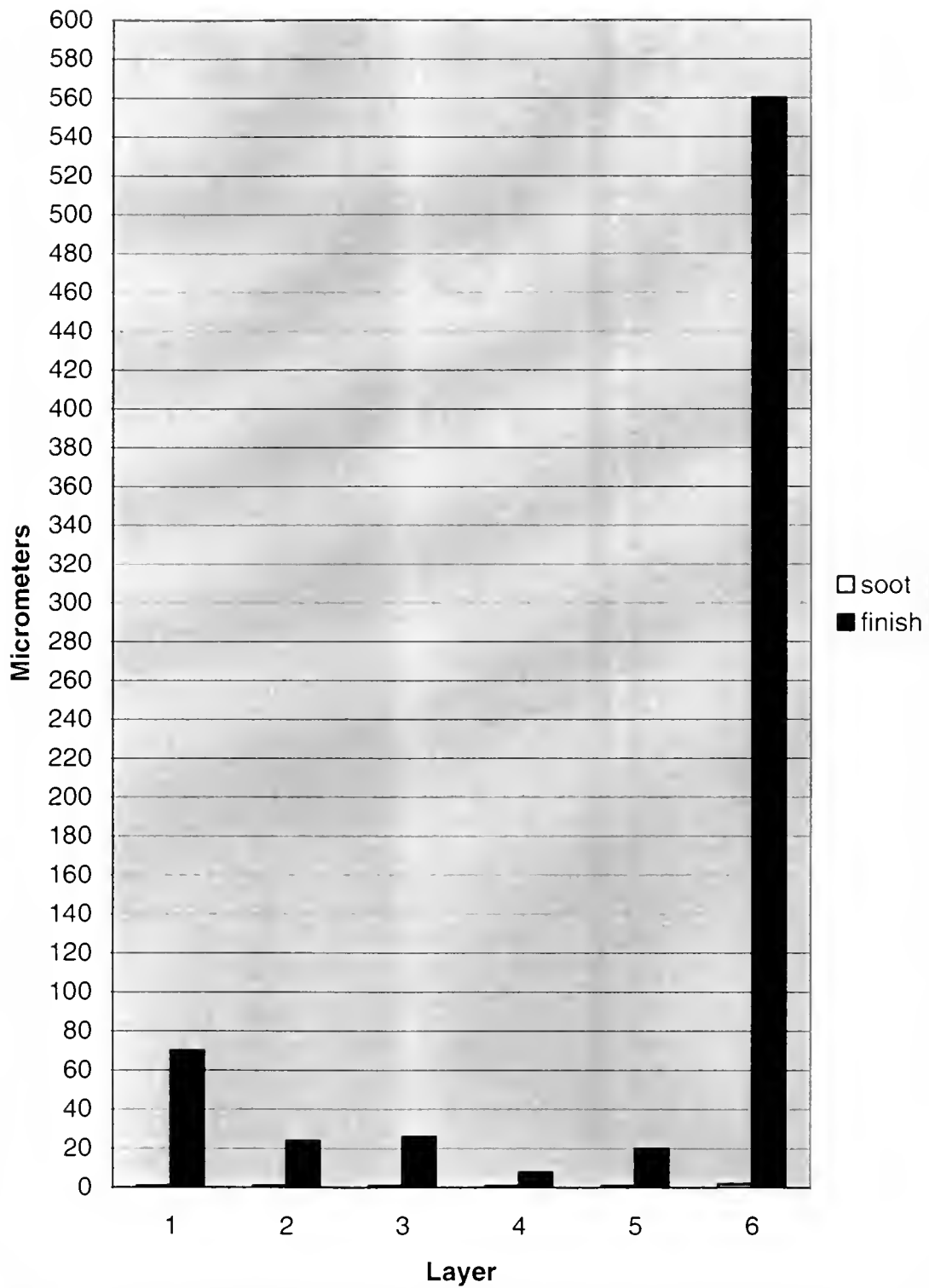
Lower North Wall,  
West Half  
Bottom (Floor) of  
Niche  
.80 m from floor  
86 m from west wall  
142

[illegible]



Lower North Wall,  
West Half  
West Wall of Niche  
.90 m from floor  
56 m from west wall  
143



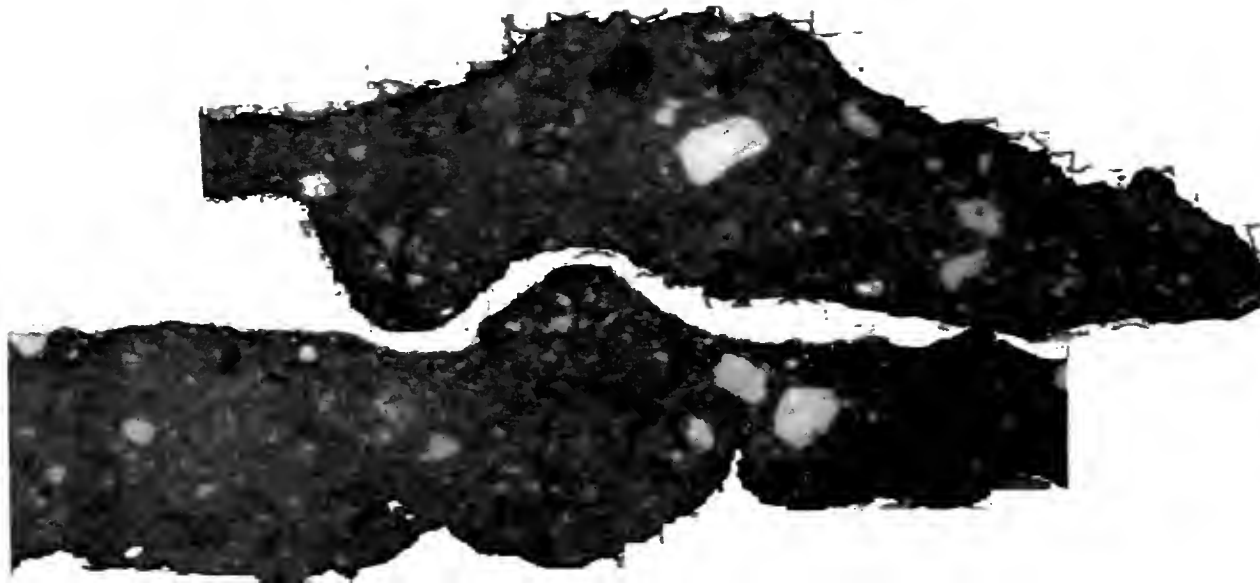
**Sample BAND M-100.10**



	surface texture	coarse fine ratio	layer color	matrix color	coarse fraction color	coarse fraction shape	coarse fraction sorting	boundary	
	wavy	30% : 70%	7.5 YR 4/1 dark gray	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	angular, spherical angular	even	sharp	
			soot					fuzzy	



	wavy	30% : 70%	7.5 YR 4/1 dark gray	7.5 YR 4/1 dark gray	GLEY 1 7/N light gray	angular, spherical angular	even	fuzzy	
							This sample was broken, and has been digitally reconstructed. There are large inclusions present in layers 1 and 3.		

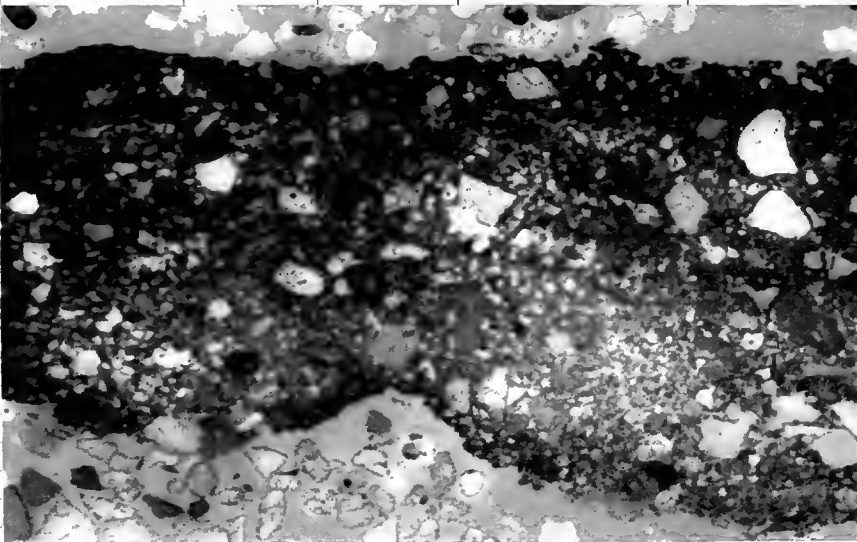






**Sample BAND 100.12**  
**Cavate M-100**  
**Frijoles Canyon**  
**Bandelier National Monument**  
**New Mexico, USA**

Upper South Wall,  
West Half  
Upper East Side of  
East Smoke Hole  
1.73 m from floor  
.63 m from West Wall  
146

	type	measurement	surface texture	coarse fine ratio	layer color	matrix color	coarse fraction color	coarse fraction shape	coarse fraction sorting	boundary			
f	soot	6.3mm			soot					fuzzy			
<div><p>This sample is pure soot accumulation.</p></div>													



**New Mexico, USA**

147

There are large inclusions present in layers 2 and 3.



<i>surface texture</i>	<i>coarse fine ratio</i>	<i>layer color</i>	<i>matrix color</i>	<i>coarse fraction color</i>	<i>coarse fraction shape</i>
wavy	40% : 60%	GLEY 1 3/N very dark gray	GLEY 1 2.5/N black	GLEY 1 8/N white	spherical subrounded
moderately rough	40% : 60%	GLEY 1 3/N very dark gray	GLEY 1 2.5/N black	GLEY 1 8/N white	spherical subrounded
moderately rough	40% : 60%	GLEY 1 3/N very dark gray	GLEY 1 2.5/N black	GLEY 1 8/N white	spherical subrounded
		soot			
very rough	40% : 60%	7.5 YR 7/3 pink	10 YR 8/3 very pale brown	GLEY 1 8/N white, 2.5 YR 7/1 light reddish gray	spherical subrounded
		soot			
moderately rough	40% : 60%	7.5 YR 7/3 pink	10 YR 8/3 very pale brown	GLEY 1 8/N white and 2.5 YR 7/1 light reddish gray	spherical subrounded
		soot			
moderately rough	50% : 50%	10 YR 8/1 white	2.5Y 6/1 gray	10 YR 8/1 white	spherical subrounded
		soot			
slightly rough	50% : 50%	10 YR 8/3 very pale brown	10 YR 8/3 very pale brown	10 YR 8/1 white	tabular angular, spherical subangular
		soot			
moderately rough	50% : 50%	10 YR 7/1 light gray	10 YR 7/1 light gray	10 YR 8/1 white, 10 YR 6/1 gray	spherical subrounded
		soot			
slightly rough	50% : 50%	10 YR 6/1 gray	10 YR 6/1 gray	10 YR 8/1 white	spherical subangular, spherical subrounded
		soot			
wavy	40 % : 60%	10 YR 4/1 dark gray	10 YR 4/1 dark gray	10 YR 8/1 white	tabular, spherical angular



Sample BAND 100.15  
Cavate M-100  
Frijoles Canyon  
Bandelier National Monument  
New Mexico, USA

There are large  
inclusions present in  
layers 1, 2, 3, 13, 15,  
and 17.

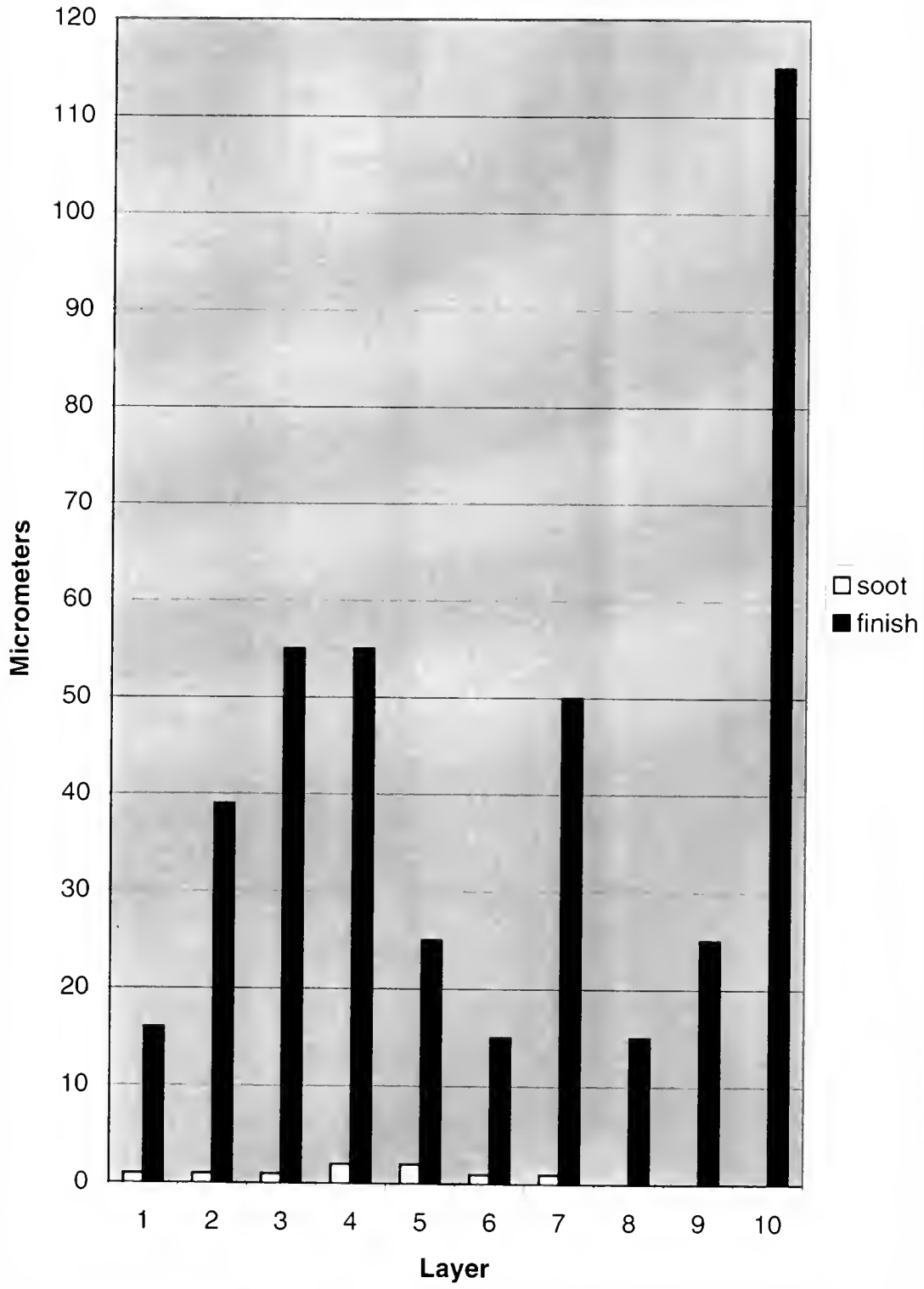


Lower North Wall,  
East Half  
Floor Sample  
17 cm from  
East Wall  
149





Sample BAND M-100.15





Sample BAND 100.19  
Cavate M-100  
Frijoles Canyon  
Bandelier National Monument  
New Mexico, USA

Lower West Wall,  
South Half  
30 cm from floor,  
1.46 m from door  
151

	<i>type</i>	<i>measurement</i>	<i>surface texture</i>	<i>coarse fine ratio</i>	<i>layer color</i>	<i>matrix color</i>	<i>coarse fraction color</i>	<i>coarse fraction shape</i>	<i>coarse fraction sorting</i>	<i>boundary</i>
1	soot	1µm			soot					sharp
2	wash	25µm	moderately rough	50% : 50%	2.5 Y 6/1 gray	10 YR 5/1 gray	10 YR 8/1 white	tabular subangular, sphenical subrounded	even	sharp
3	soot	1µm			soot					sharp
4	wash	15 µm	moderately rough	50% : 50%	2.5 Y 6/1 gray	10 YR 5/1 gray	10 YR 8/1 white	tabular subangular, sphenical subrounded	even	sharp
5	soot	3µm			soot					sharp
6	wash	20µm	moderately rough	50% : 50%	10 YR 4/2 dark grayish brown	10 YR 4/2 dark grayish brown	GLE Y 1 7/N light gray	subspherical subrounded	even	sharp
7	soot	1µm			soot					sharp
8	wash	45µm	moderately rough	45% : 55%	10 YR 5/2 grayish brown	10 YR 5/3 brown	GLE Y 1 7/N light gray	tabular subangular, sphenical subangular	even	sharp
9	soot	4µm			soot					sharp
10	wash	8µm	very rough	50% : 50%	10 YR 4/2 dark grayish brown	10 YR 4/2 dark grayish brown	GLE Y 1 7/N light gray	sphenical subrounded	even	sharp
11	soot	1µm			soot					sharp
12	wash	32µm	very rough	50% : 50%	10 YR 4/2 dark grayish brown	10 YR 4/2 dark grayish brown	GLE Y 1 7/N light gray	sphenical subangular, spherical subrounded	even	sharp
13	soot	1µm			soot					sharp
14	wash	50µm	moderately rough	50% : 50%	2.5 Y 4/2 dark grayish brown	2.4 Y 4/1 dark gray	GLE Y 1 7/N light gray, 10 YR 6/1 gray	spherical subrounded, tabular subangular	uniform, some clusters	sharp
15	soot	1µm			soot					fuzzy
16	wash	12µm	moderately rough	40% : 60%	10 YR 4/3 brown	10 YR 4/3 brown	GLE Y 1 7/N light gray	spherical subrounded	uniform	fuzzy
17	soot	1µm			soot					fuzzy
18	wash	15µm	moderately rough	40% : 60%	10 YR 4/3 brown	10 YR 4/3 brown	GLE Y 1 7/N light gray	sphenical subrounded	uniform	fuzzy
19	soot	1µm			soot					sharp
20	wash	30µm	moderately rough	40% : 60%	10 YR 4/3 brown	10 YR 4/3 brown	GLE Y 1 7/N light gray, 10 YR 6/1 gray	sphenical subrounded, tabular angular	uniform	sharp
21	soot	1µm			soot					fuzzy
22	wash	35µm	very rough	40% : 60%	10 YR 4/3 brown	10 YR 4/3 brown	GLE Y 1 7/N light gray, 10 YR 6/1 gray	spherical subrounded	uniform, some clusters	fuzzy



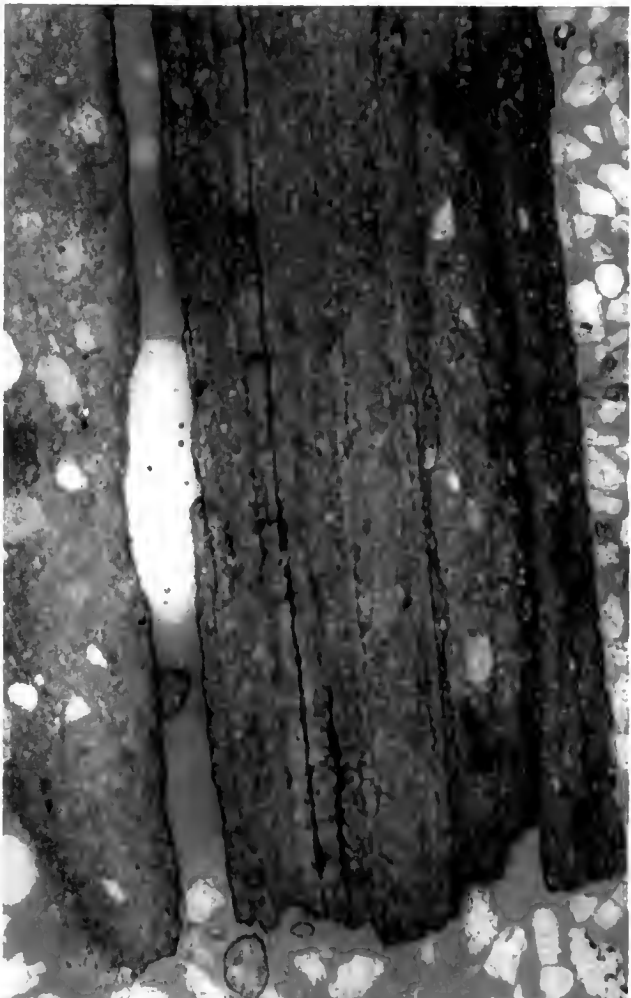
## New Mexico, USA

52

\*Layer 36 is broken, appears on both sides of the break.



Sample BAND 100, 19  
Cavate M-100  
Frijoles Canyon  
Bandelier National Monument  
New Mexico, USA



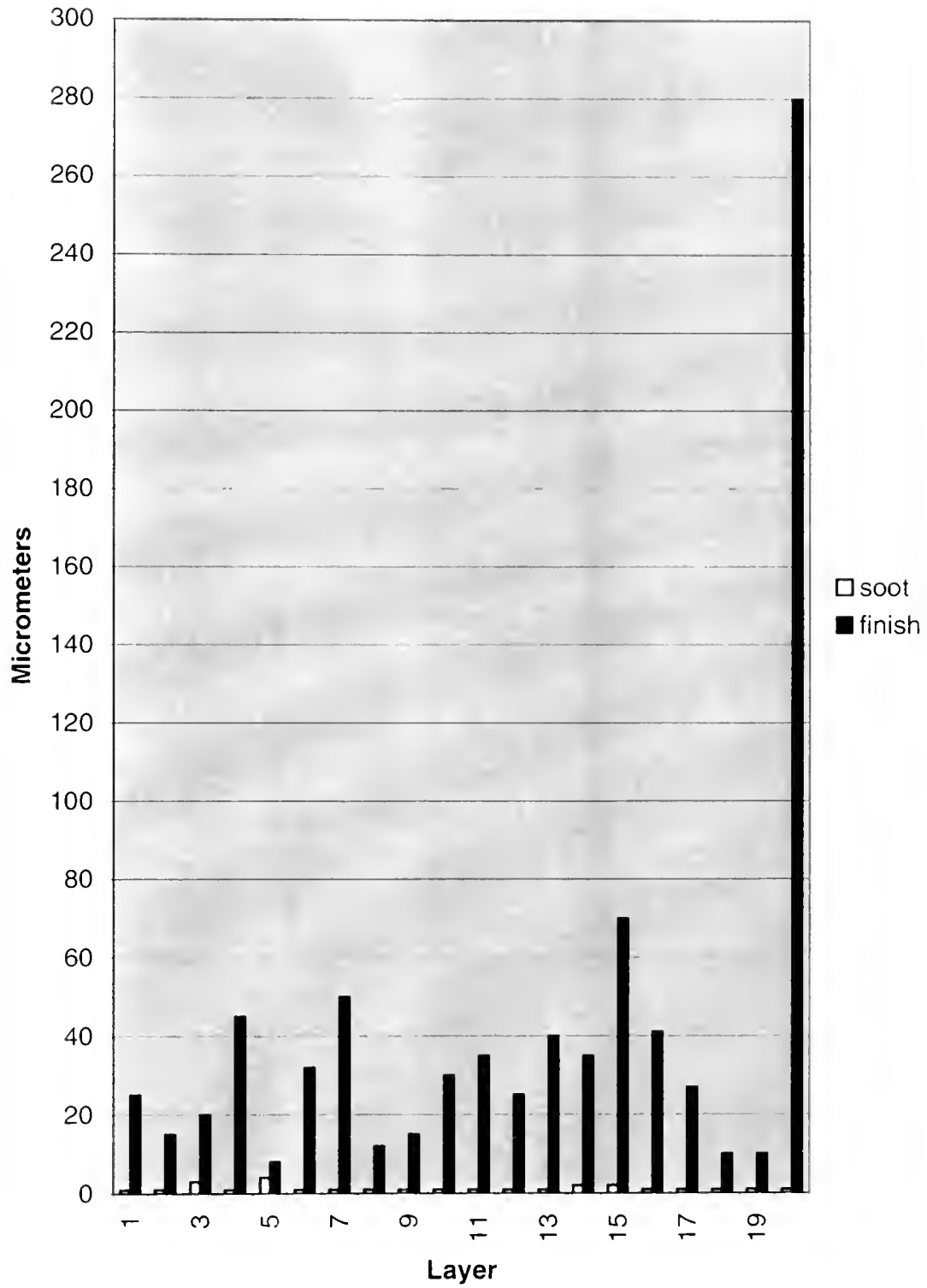
There are large inclusions present  
in layers 4, 12, 16, and 40.

Lower West Wall,  
South Half  
30 cm from floor,  
1.46 m from door  
153





## Sample M-100.19

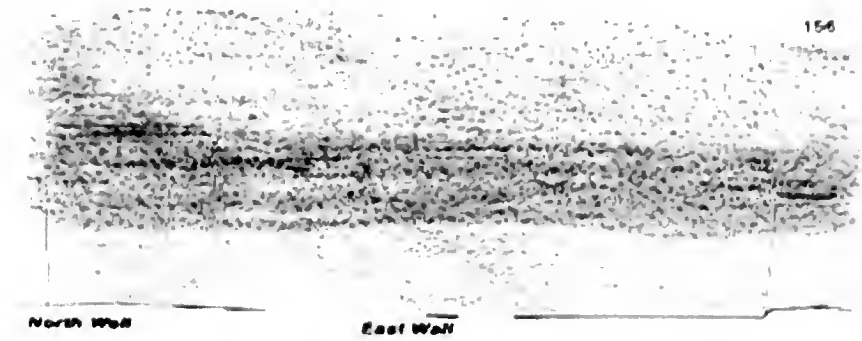




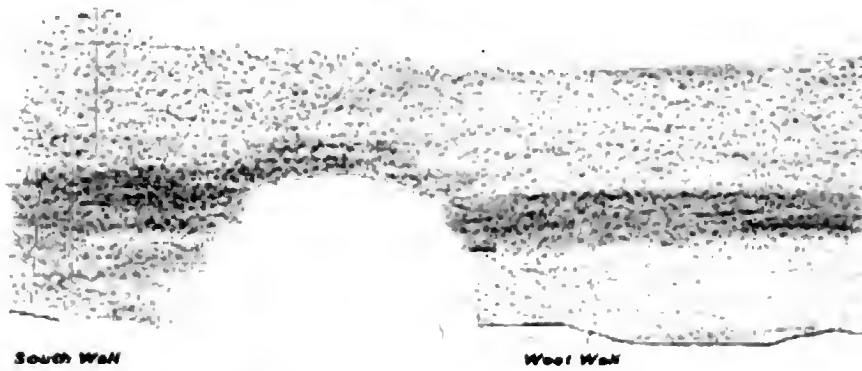
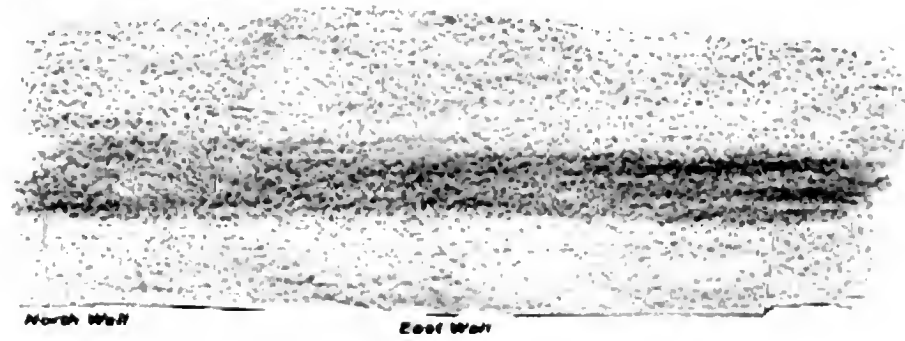
## **Appendix E**

### **Conjectural Finish Schemes**



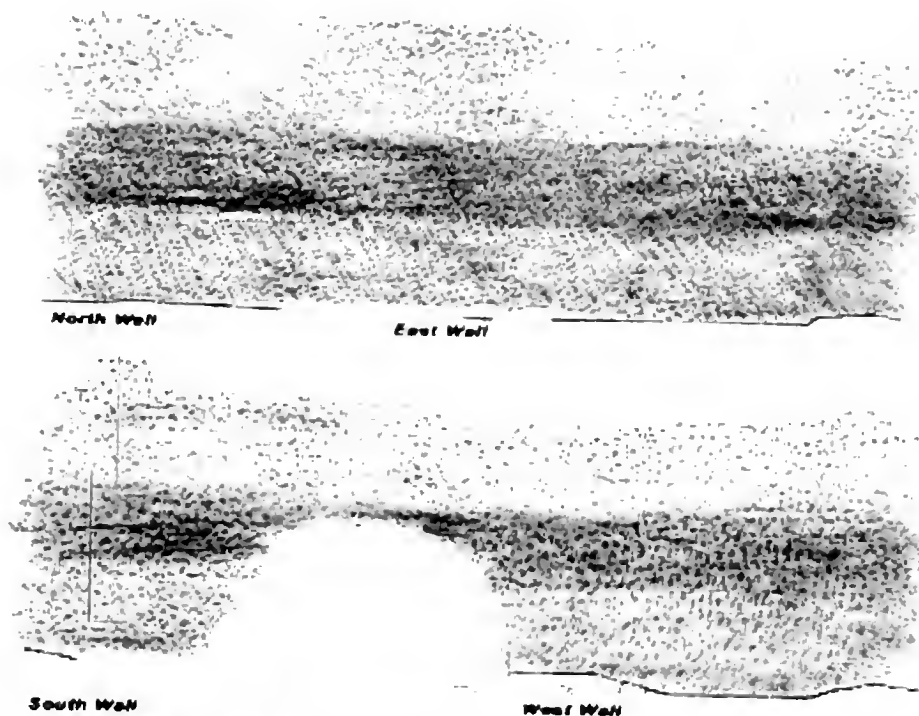


**Initial Scheme**

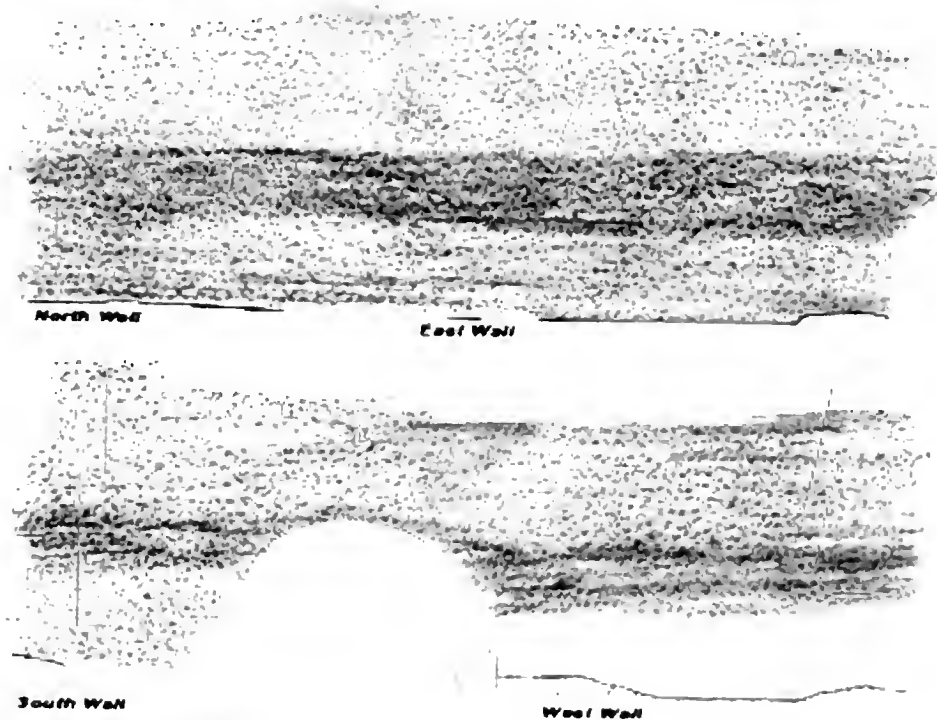


**Potential Scheme 1**





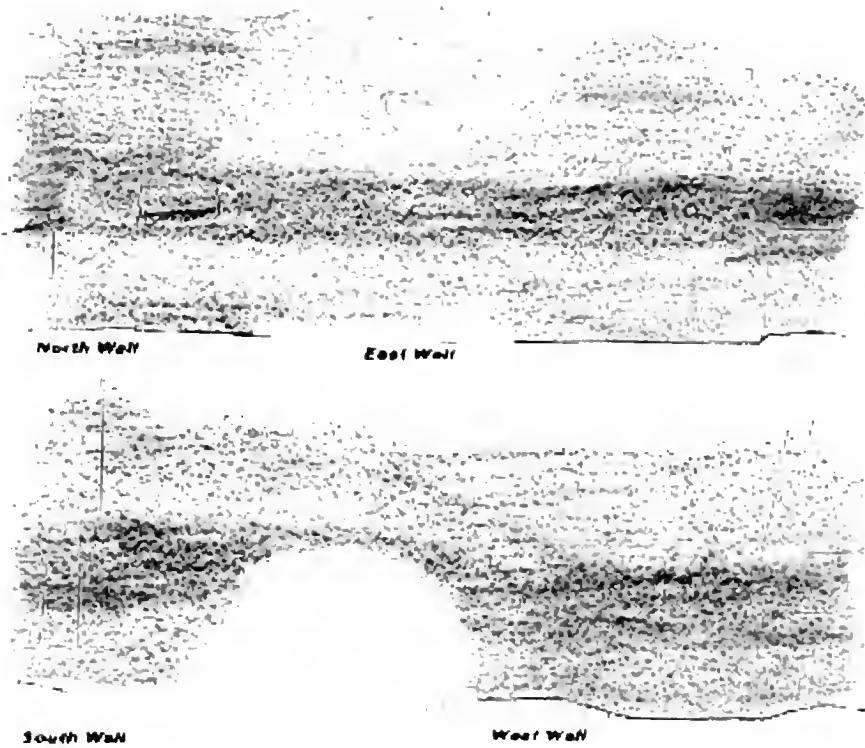
Potential Scheme 2



Potential Scheme 3







Present Scheme



## **Appendix F**

### **Glossary of Thin Section Terms**



All term taken from *Soil Microscopy and Micromorphology*, E.A. FitzPatrick, John Wiley & Sons, 1993, unless otherwise noted.

**Assemblage**—The totality of all the soil components and features and their interrelationships, e.g. sand, silt, clay, organic matter, porosity, clay coatings, concretions, etc.

**Fabric**—The arrangement, size, shape and frequency of the individual solid soil components within the soil as a whole and within features themselves.

**Matrix**—Material forming a more or less continuous phase and enclosing coarse material, concretions, etc. Generally refers to material  $< 2\mu\text{m}$  but can be much larger. Clay matrices are often uniform in color but they may be speckled.

**Color**—May be different in transmitted and reflected light. Can vary with thickness. Sample that appears to have uniform color may really have pattern

marbled

speckled

spotted

streaked

Wide range of translucence, ranging from transparent through strongly, moderately and weakly translucent to opaque. Given in Munsell notations.

**Clast**—a large fragment such as a pebble that is significantly larger than the surrounding material.

**Deposition**—the sedimentation of material on to a surface ....Some deposited materials eventually become integrated or assimilated into the matrix.





















**Finish**—coat of paint or plaster laid upon a surface<sup>1</sup>

<b>Size</b> — Very large	$> 10,000 \mu\text{m}$ (10 mm)
Large	2,000-10,000 $\mu\text{m}$ (2-10 mm)
Medium	200-2,000 $\mu\text{m}$
Small	60-200 $\mu\text{m}$
Very Small	2-60 $\mu\text{m}$
Micro	$< 2 \mu\text{m}$

<sup>1</sup> Oxford English Dictionary, [www.oed.com](http://www.oed.com).



48 PROPERTIES OF FEATURES IN THIS SECTION

Spherical					
Subspherical					
Ovoid					
Tabular					
	Angular	Subangular	Subrounded	Rounded	Well rounded

**Shape—**

**Roundness**—refers to the sharpness of edges and corners irrespective of the form.

**Angular**—Definite faces with sharp edges and corners.

**Subangular**—Definite faces with slightly rounded edges and corners.

**Subrounded**—Rounded edges and corners and not many flat faces.

**Rounded**—All edges and corners are broad curves; there are many reentrant angles but flat faces are rare.

**Well rounded**—The entire surface consists of broad curves; no flat faces.

**Sphericity**—refers to the overall form of a feature irrespective of the sharpness of the edges and the corners; it is a measure of the degree of conformity of the shape to that of a sphere

**Tabular**—Elongate with almost parallel sides.

**Ovoid**—Oval but having one distinct long axis.

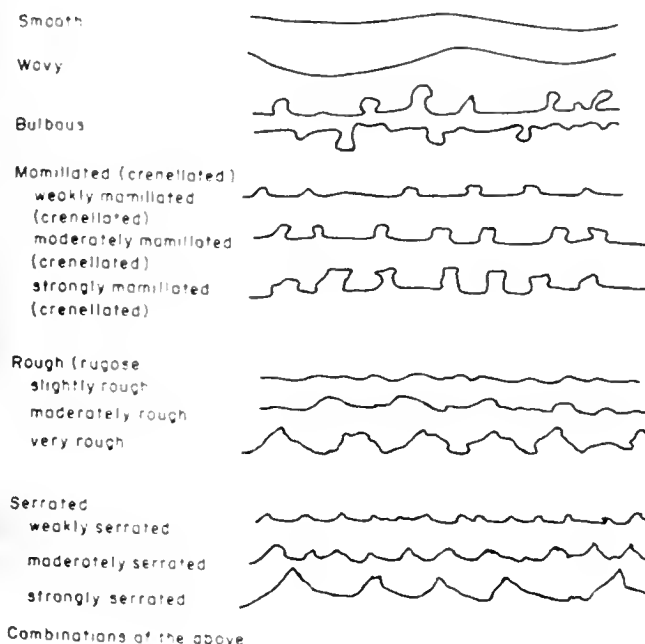
**Subspherical**—Tending to be equal in all directions.

**Spherical**—Equal in all directions.

**Surface Characteristics—**







**Bulbous**—With many bulb-like features.

**Embayed**—Deep gully-like features into mineral surfaces.

**Etched**—Clearly developed regular pattern.

**Fractured**—Surface caused by breaking; some types of fractures are distinctive such as the conchoidal fractures in quartz.

**Mamillated (crenellated)**—Like battlements.

**Pitted**—Small indentations in a surface; they may differ in shape or they may be all the same.

**Rough (rugose)**—Rough irregular pattern.

**Serrated**—Like the teeth of a saw.

**Striated**—Small parallel or subparallel grooves in a surface.

**Wavy**—Undulating with gentle waves.

**Combinations of the above.**

**Boundaries**—**Abrupt** <100  $\mu\text{m}$

**Sharp** 100-500  $\mu\text{m}$

**Clear** 500-1000  $\mu\text{m}$

**Diffuse** >1000  $\mu\text{m}$

**Relationships between features:**

**Banded**—The features occur in alternating bands.



**Clustered**—Occurring in clusters—the clusters vary in closeness of the individuals and may be:

**Dense**—closely spaced units with little visible space between the units

**Even**—approximately equidistant with clear spaces between the units

**Uneven**—irregular distribution of the individuals

**Wide**—widely spaced units

**Intimate**—The two or more features present are intimately associated with each other.

**Normal**—The feature is arranged at right angles to some other feature.

**Parallel**—The features are parallel to each other.

**Unrelated**—The feature has no fixed relationship with any other feature with any other feature. The relationship may be said to be haphazard.

**Plaster**— A composition of a soft and plastic consistency, which may be spread or daubed upon a surface, as of a wall, where it afterwards hardens<sup>2</sup> 1 mm or thicker

**Wash**— A thin coat of water-color or distemper spread over a wall or similar surface; a preparation used for this purpose.<sup>3</sup> Less than 1 mm in thickness.

### **Distribution Patterns**

**Banded**—Occurring in bands; may or may not be parallel

**Clustered**—Occurring in clusters of groups

**Even**—Approximately equally spaced

**Random**—In an irregular manner

**Uniform**—Evenly spaced

**Mixtures of the above**

<sup>2</sup> Oxford English Dictionary, [www.oed.com](http://www.oed.com)

<sup>3</sup> Ibid.



**B**

Bandelier, Adolf, 5, 9, 67  
 Bandelier National Monument, 1, 2,  
     3, 5, 7, 8, 9, 10, 11, 12, 13,  
     14, 15, 16, 17, 18, 19, 20, 21,  
     26, 27, 28, 33, 39, 63, 77  
 Bandelier Tuff, 6, 15

**C**

Cavate, 1, 2, 3, 4, 5, 7, 9, 10, 11, 12,  
     13, 14, 15, 16, 17, 18, 19, 20,  
     22, 23, 24, 25, 26, 27, 32, 33,  
     35, 36, 37, 38, 39, 40, 41, 45,  
     46, 50, 51, 52, 53, 54, 55, 57,  
     59, 62, 63, 64, 65, 66, 67, 68,  
     69, 71, 72, 73, 74, 75, 76, 77,  
     79  
 Chapman, 10, 17, 38, 72  
 Color, 4, 27, 28, 30, 37, 40, 43, 44,  
     45, 46, 47, 48, 49, 50, 51, 52,  
     53, 54, 55, 56, 57, 58, 59, 61,  
     62, 68, 71  
 Conditions Survey, 26, 27, 28, 29  
 Conductance, 59, 61, 62

**E**

Embellishments, 2, 4, 10, 19, 21, 22,  
     24, 25, 27, 28, 29, 37, 38, 65,  
     66, 67, 72, 73, 74, 76

**F**

Finishes, 1, 3, 4, 19, 23, 27, 32, 33,  
     34, 37, 39, 40, 41, 45, 48, 50,  
     55, 57, 58, 64, 67, 68, 69, 71,  
     74, 75, 76, 77, 78, 79

**G**

Group M, 10, 12, 13, 20, 21, 22

**H**

Hendron, J.W., 10, 12, 13, 22  
 Hewett, Edgar Lee, 5, 9, 10, 11, 19,  
     68, 72

**L**

Lister, R.W., 11, 12, 14

**M**

M-100, 3, 4, 12, 13, 14, 19, 22, 24,  
     26, 27, 30, 32, 33, 34, 35, 36,  
     37, 38, 39, 40, 41, 42, 45, 46,  
     55, 57, 64, 65, 66, 67, 68, 69,  
     70, 71, 72, 74, 75, 76, 77

**P**

Plaster, 33, 34, 35, 36, 37, 39, 44,  
     50, 56, 57, 58, 59, 60, 61, 63,  
     65, 68, 69, 70, 71, 72, 74, 75  
 Puebloan, 3, 12, 17, 18, 20

**S**

Smith, Watson, 64, 68, 72  
 Soluble salts, 7, 61  
 Stratigraphies, 3, 40, 69

**T**

Thin section, 25, 34, 41, 42, 43, 71,  
     72, 75, 79  
 Toll, H. Wolcott, 1, 7, 9, 10, 11, 21,  
     22, 27

**W**

Wash, 23, 24, 25, 27, 34, 36, 37, 39,  
     44, 45, 58, 59, 63, 64, 69, 70,  
     71, 72, 75





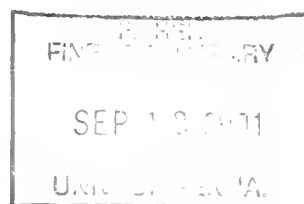
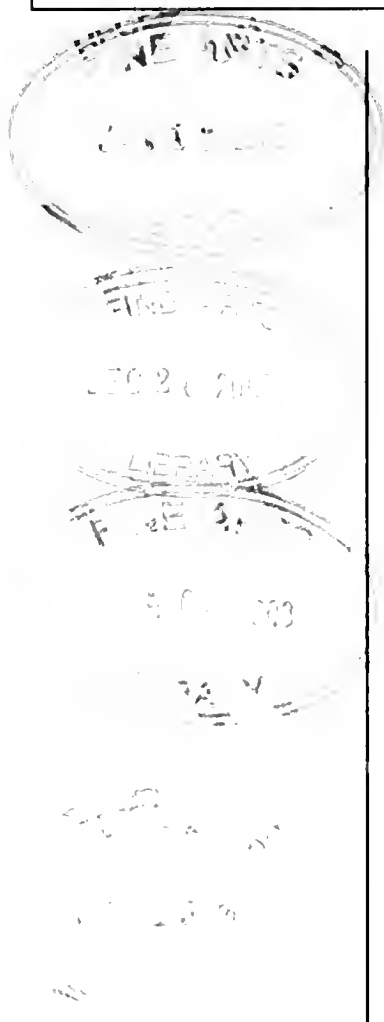






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